1.0 INTRODUCTION

The protection, conservation, and restoration of forested riparian areas along rivers and streams can offer a wide range of potential benefits. These benefits include ecological enhancements such as improved water quality, greater wildlife diversity, and a more natural flow regime, as well social benefits such as educational opportunities, enhanced aesthetics, reduced flooding, a higher quality of life for residents, and increased civic pride.

This report describes a study conducted to identify, evaluate, and prioritize riparian buffer restoration opportunities on the Woonasquatucket River in Rhode Island. The study was directed by the Woonasquatucket River Watershed Council and funded by a grant from the U.S. Forest Service. Results from the study, as described below, are intended to aid future resource management decisions in the watershed. In particular, this report and its supporting information are designed to provide not only a comprehensive inventory of potential riparian restoration sites, but a tool for prioritizing and selecting projects for future funding and implementation. The study also includes guidelines for restoration design that take into account specific characteristics of the subject watershed. Finally, the study includes the identification and implementation of a demonstration restoration site in the watershed, as described in Section 6 of this report. The design work for the demonstration restoration project was completed by Kleinschmidt during the Summer of 2001, and the implementation is scheduled for 2002.

The following subsections briefly describe the character and existing condition of the Woonasquatucket River watershed, the purpose of the study, and how this report can be used to facilitate future planning and implementation. Following this introduction, Section 2 provides an overview of the study methods employed, Section 3 presents results of the inventory, and Section 4 describes specific uses for the study results. Section 5 presents information on buffer design considerations relevant to the Woonasquatucket watershed, and Section 6 describes selection and implementation of the proposed demonstration site. Several appendices provide additional information, including detailed site descriptions for each of the potential riparian restoration sites identified.

1.1 Woonasquatucket Watershed

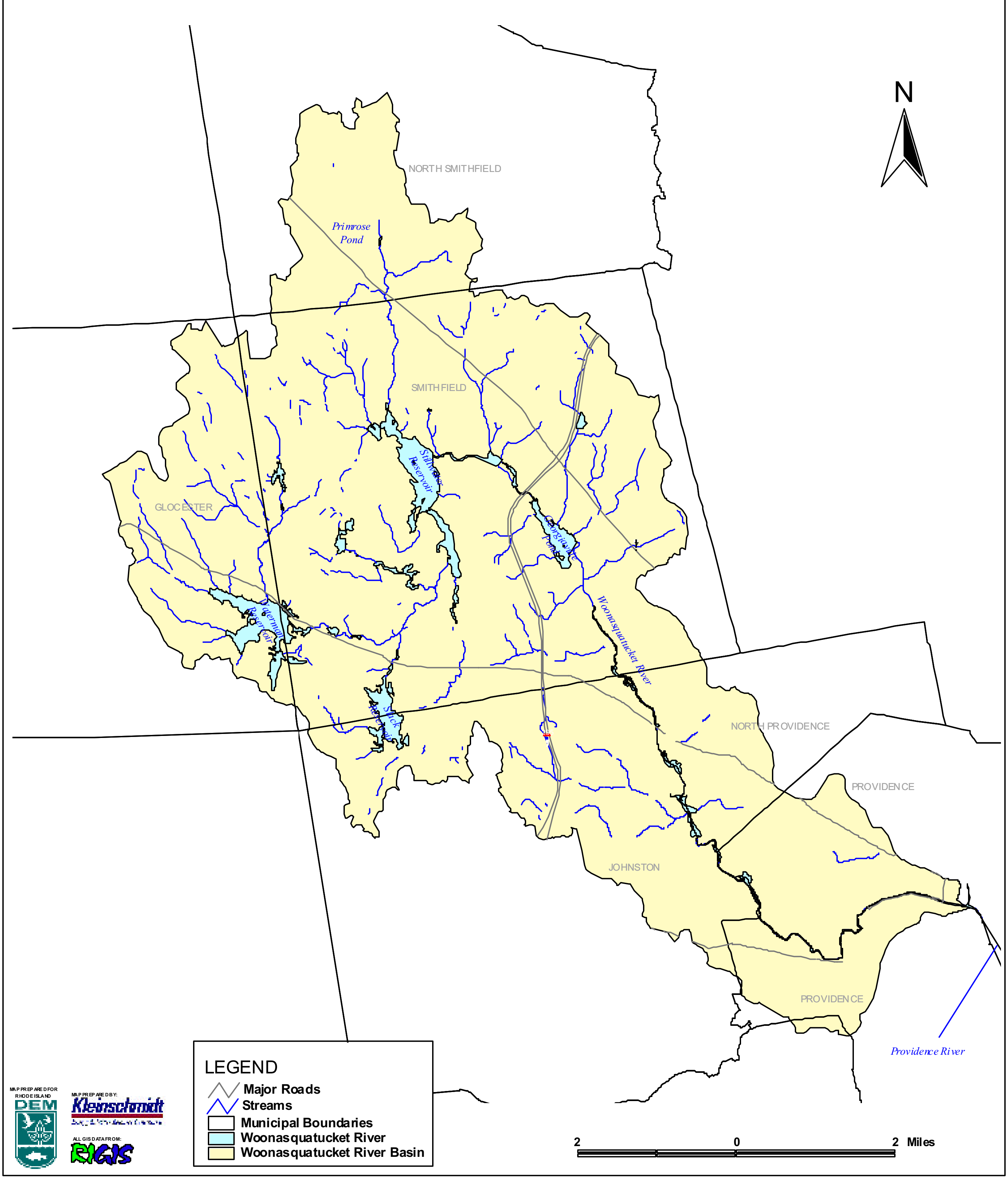
The Woonasquatucket River watershed extends from its headwaters near Primrose Pond in North Smithfield to the City of Providence (Figure 1-1). In Providence, the River merges with the Moshassuck River forming the Providence River, which drains into Narragansett Bay. The watershed is approximately 52 square miles in area, and drops more than 200 feet in elevation along its 19 mile length (Louis Berger, 2000). Along the way, it flows through two relatively large reservoirs (Stillwater Reservoir and Georgiaville Pond) in Smithfield, and through several small old mill ponds in North Providence, Johnston, and Providence. Due to the watershed's industrial heritage, dams are prevalent. There are 18 dams along the Woonasquatucket, and 20 additional dams on tributaries (Louis Berger, 2000).

There are six municipalities that are located within the Woonasquatucket River watershed; Glocester, North Smithfield, Smithfield, Johnston, North Providence, and Providence. Tables 1-1 and 1-2 summarize area and population data for each of these six municipalities. Smithfield is the only municipality that is almost entirely within the watershed, and it comprises almost half of the total watershed area. Approximately half of the population within the watershed is in Providence. More than a quarter of the state's population lives in a town that has at least some of its area in the Woonasquatucket River watershed.

Along the river corridor most of the surficial material consists of recent alluvium (river-deposited sediments), glacial outwash, and cut-and-fill material (also known as Udorthents). The glacial outwash includes both ice-contact outwash features (such as kames and eskers), and outwash plains (where the meltwater-sorted deposits were laid-down away from the immediate ice margin). By contrast, higher elevations in the watershed (*i.e.*, the northern part of the watershed and outer portions, away from the river) have a dominant surficial material of glacial till and the landscape is more bedrock-controlled (USDA, 1981). In less developed portions of the watershed, from around Dyerville State Park in Johnston and upstream, the gentle topography has allowed extensive floodplains and streamside wetlands to form along many river stretches. If

Figure 1-1

Woonasquatucket Watershed Boundary Map



similarly well-developed floodplains and streamside wetlands once occurred through the Providence section of the river, the majority of them have been filled and paved-over.

Land use patterns within the watershed range from primarily forested and agricultural lands in the upper watershed to densely populated urban areas in the lower watershed. Figure 1-2 displays several representative photographs of the various conditions found along the river throughout the watershed. Riparian buffer restoration opportunities along the river are largely a function of these various existing land uses. Based on existing University of Rhode Island's RIGIS program land use coverages, the riparian corridor along the Woonasquatucket main stem is approximately 81% non-forested (about 3,669 acres) and 19% forested (874 acres) in the area within 400 feet of the river edge. Approximately 682 acres (about 80%) of riparian forestlands in the 400 foot riparian buffer along the main stem are in Smithfield.

The lower portion of the Woonasquatucket River watershed is densely populated and much of the contributing watershed consists of impervious surfaces such as roads, roofs, and parking lots. Stormwater and associated pollutants from these surfaces typically drain directly to the River via storm drains without adequate polishing from buffers or stormwater treatment systems. Much of the river is lined with floodwalls or retaining walls, and vegetated buffers are either of inadequate width or non-existent in most places. In portions of downtown Providence, such as along Promenade Street, the River is channelized (*i.e.*, straightened and contained within floodwalls). Floodwalls and channelization have eliminated the natural sinuosity of the River and segregated it hydrologically from existing and historical riparian buffers and floodplains. Old mills, both defunct and operational, are common along the immediate river banks in the lower portion of the watershed and several of the potential restoration sites evaluated were mill sites. Other types of industrial and commercial development are also common along the immediate river bank, including shopping centers, offices, and parking facilities.

The middle portion of the watershed (*i.e.* North Providence and Johnston) is characterized by more suburban development with considerable commercial and industrial development directly along the river, including auto salvage yards and sand and gravel mining operations. Large-scale commercial and industrial land uses are especially

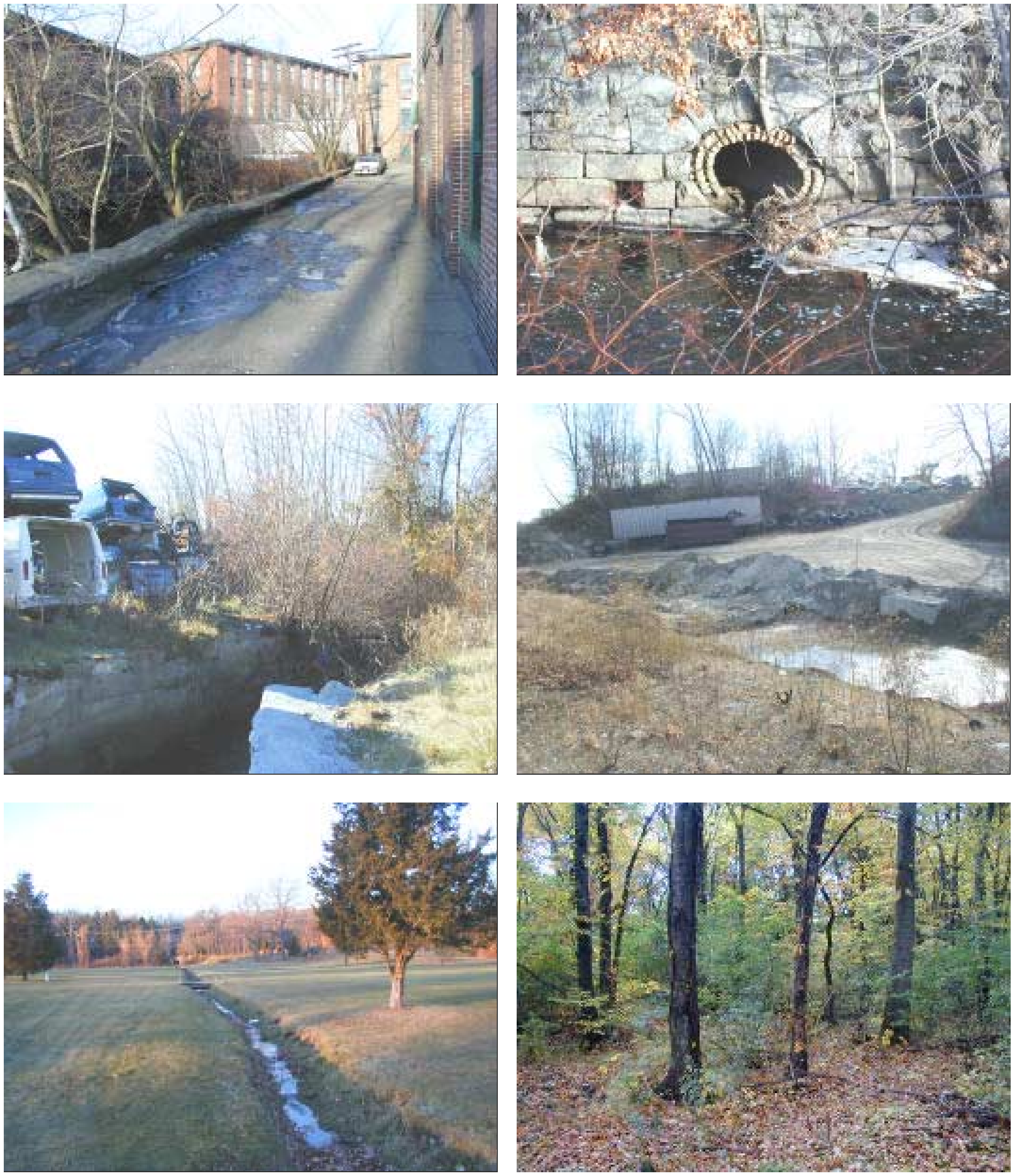


Figure 1-2. Representative Photos of Watershed Sections.

The lower portion of the watershed is characterized by floodwalls, old mill sites, and impervious surfaces (upper two photos). The middle portion of the watershed contains a large number of sand and gravel pits, auto salvage yards, and commercial properties in the buffer zone (middle two photos). The upper portion of the watershed is characterized by a relative lack of floodwalls and impervious surfaces in the riparian buffer. Restoration opportunities typically involved mowed and maintained areas such as golf courses, parks, DOT properties, and residences (lower left photo). In the upper part of the watershed intact riparian forest buffers (reference conditions) are more common (lower right photo).

prevalent in Johnston. The prevalence of mining operations results from the outwash overburden (*i.e.*, coarse-textured, water-sorted materials such as sand and gravel) discussed above. Several open space areas, such as parks, building grounds, or DOT properties, also occur along the river and its tributaries in this area of the watershed. Many of these areas are dominated by managed vegetation and lawn, rather than naturally vegetated buffers.

The upper portion of the watershed (*i.e.*, Smithfield, North Smithfield, Glocester, and western Johnston, away from the River), by contrast, is more extensively buffered, lacks retaining walls, and is less densely populated. The vast majority of the watershed's wetlands and tributary streams are located in this portion of the watershed (Louis Berger, 2000), as are the majority of "reference sites" (Figure 1-2). Unlike the middle and lower portions of the watershed, land uses include agriculture (orchards and croplands), low-density residential areas, and relatively large areas of open space. On the other hand, many of the same uses found in the lower portion of the watershed also occur here. These include old mill/industrial sites, some commercial sites, parks and open space areas, DOT parcels, municipal/public works, and residential areas.

A significant component of the riparian plant community in the Woonasquatucket watershed consists of exotic and invasive species. This is especially true in the lower portion of the watershed. The most ubiquitous exotic/invasive species in the watershed is Japanese knotweed (Fallopia japonica) (Figure 1-3). A more detailed description of the exotic/invasive species in the watershed is presented in Section 5. However, even in the lower portions of the River, in and near Providence, there are relatively undisturbed riparian buffers that lack a dominance of exotic/invasives. Such sites are call "reference sites" which are relatively intact, undisturbed forested riparian buffers that are dominated by native vegetation and natural soil profiles (Figure 1-4). These sites typically provide riparian buffer functions at target levels, and their characteristics can help with restoration designs. For example, riparian buffer site designs for the Woonasquatucket River should attempt to use native plants characteristic of undisturbed portions of the River (*i.e.*, reference sites), if commercially available, since these plants are known to thrive in the local conditions.

Figure 1-3. Japanese knotweed.

Japanese knotweed along a floodwall in Olneyville, Providence.

Figure 1-4. Reference condition.

This relatively undisturbed riparian buffer is just downstream from the Allendale Mill Dam in Johnston and North Providence. Native species such as green ash, red maple, red oak, black cherry, and American elm dominate the tree stratum.

1.2 Project Purpose

This project is intended to work in conjunction with other ongoing and proposed efforts to restore the Woonasquatucket River as a natural asset, contributing to the environmental, cultural, and recreational and economic health of the watershed and its communities. The primary purpose of this study is to promote the improved health of the Woonasquatucket River watershed by providing a baseline of information on riparian buffer restoration opportunities that can be used to guide enhanced management and stewardship of forestland within the watershed.

Specific objectives of the study included:

- Development of a comprehensive listing of candidate sites for riparian forest buffer restoration;
- Evaluation and prioritization of identified riparian restoration opportunities (based on potential benefits and costs); and
- Creation of a riparian buffer showcase site.

1.3 How to Use this Report

This report has been specifically designed to serve as a tool for selecting and pursuing suitable riparian restoration projects. This tool begins with Section 3 which presents a comprehensive listing of suitable candidate sites for riparian forest buffer restoration as well as evaluative information on the respective benefits and costs associated with each site. These data, which are also contained in a companion database, can be used to sort and prioritize potential restoration opportunities based on specific criteria. Once potential restoration sites have been identified that meet the pre-specified criteria, the detailed site descriptions and aerial photo maps contained in Appendices A and B can be used to obtain more information about the highlighted sites. This information can be used as the basis for grant applications, permit requirements, or other restoration purposes. Design information contained in Section 5 can also be applied to assist in the development of more detailed implementation plans. Section 4 provides additional detail on the use of study results for future planning and implementation.

Table 1-1. Watershed area data by municipality.

Municipality	Area (sq. mi.)	Portion of Watershed in Municipality (%)	Portion of Municipality in Watershed (%)
Smithfield	27.6	48	88
Johnston	24.3	15	32
Glocester	56.8	12	11
Providence	18.7	11	30
North Smithfield	24.9	9	18
North Providence	5.8	5	44
Total	**158.3**	**100.0**	**-**

Table 1-2. Watershed population data by municipality.[(1)]

Municipality	Population [(2)]	Approximate Population in Watershed [(3)]	Approximate Portion of Total RI Population [(4)] (%)
Smithfield	19,142	16,820	1.7
Johnston	26,588	8,519	0.9
Glocester	9,358	1,000	0.1
Providence	149,887	44,446	4.5
North Smithfield	10,041	1,772	0.2
North Providence	31,155	13,578	1.4
Total	**246,171**	**86,135**	**8.8**

(1) Note that a very small portion of Cranston falls within the watershed (significantly less than 1% of the watershed).

(2) As of 7/1/99, based on 1999 U.S. Census Bureau data.

(3) Rough estimate assuming even population distribution within each town. Specifically, percentage of municipality in watershed multiplied by population of town.

(4) Total population of Rhode Island: 990,819.

2.0 METHODS

The project work was divided into three phases: 1) identify potential restoration sites; 2) evaluate those sites; 3) summarize restoration design recommendations that consider watershed characteristics and organize the information gathered into a database useful for future projects. While the most immediate application of this work was the selection of a specific site for a forested riparian buffer demonstration project, the information will also be used in the future for projects with different criteria than this one. Therefore, it was also important to gather sufficient information and organize it in an appropriate manner so as to be useful in these potential restoration applications. The final phase of this project, implementation of a riparian buffer restoration, is described in Section 6 of this report.

2.1 Identification of Potential Sites

The primary means of identifying potential restoration opportunities was the existing knowledge of the project area obtained from watershed residents, state and federal agencies, non-governmental organizations (NGOs), and municipalities. Information on wetland sites was made available by researchers at the University of Rhode Island from previous work that they had done in the vicinity that was funded by a wetlands restoration grant from the EPA, and meetings were held with researchers familiar with restoration opportunities in the watershed. The Department of Environmental Management (DEM) and several NGOs involved with this project had local familiarity and a number of sites already in mind that were considered good restoration opportunities. The Natural Resources Conservation Service (NRCS) also contributed valuable knowledge of restoration opportunities in the watershed from a previous survey. Other sources of nominated sites included the Woonasquatucket River Watershed Council (WRWC) and municipal officials. Several meetings with the WRWC and the Urban Rivers Team provided an opportunity to discuss both specific restoration opportunities and broader watershed issues, such as riparian buffer functions and restoration approaches. A preliminary reconnaissance visit to several sites on October 17, 2000 with the DEM and others also helped to lay the groundwork for field evaluations in November and December of 2000.

In order to gather input from others with knowledge of the area, a site nomination form (Appendix C) was developed and distributed as widely as possible to government agencies and NGOs. The introduction to the form discussed the origin of the project, the functions served by forested riparian buffers, and the site characteristics that make for an attractive restoration opportunity. The form itself consisted of questions regarding the location, ownership, and characteristics of the site, as well as contact information for the person filling out the form. Several people who did not actually return forms were at least prompted by the forms to call with information on sites that they considered relevant.

Field work also helped to locate potential sites. While traveling between sites previously identified by other means, field workers made note of potential restoration sites that they came across along the way and noted them for a return visit, or filled out evaluation forms as necessary. There are far more potential riparian buffer restoration sites in the watershed than were evaluated. Literally hundreds could be identified, but those evaluated were seen as having the best potential with regard to gains in riparian buffer function and other practical aspects, such as access, land ownership, etc. It was felt that collecting more detailed and comprehensive data on a few dozen sites, such as these, was preferable to collecting less comprehensive data on several hundred potential sites.

The best potential sites were considered to be those that were significantly degraded in the existing condition and which could potentially be modified to restore lost or degraded buffer characteristics. Examples included sites where forest had been replaced by mowed lawn, fill, trash, or abandoned impervious surfaces. Other potential sites included buffers with poorly functioning stormwater systems (*e.g.*, concentrated runoff that carries sediment and pollutants directly to the river through paved swales, eroded gullies, or pipes, limiting infiltration into the soils of naturally vegetated cover types), soil erosion, or unstable stream banks. All sites were immediately adjacent to the Woonasquatucket River (including the waterbodies formed by dams along its length) or one of its tributaries.

2.2 Evaluation of Sites

The overall goal of the site evaluations was to characterize the existing condition at each site and identify specific components of the restoration opportunity, including rough cost estimates, as a basis for isolating the best potential restoration sites. Although resources such as aerial photos and the Soil Survey of Rhode Island were used, the majority of the information gathered was field-based since this information was much more detailed and thorough than that available from desk-top resources alone. One specific objective was to collect sufficient data to allow rating of potential sites according to the degree that specific riparian buffer functions could be enhanced or restored. So, for example, the end user could isolate the best opportunities for water quality improvement individually, or determine the best opportunities overall considering all four rated functions. Another objective was that the data be sufficient to consider the ratio of estimated restoration gain to estimated costs.

Prior to the commencement of field work, a site evaluation form (Appendix D) was developed to ensure that all the necessary information was gathered at each site. The form was also meant to make information gathering as consistent as possible from one site to another and potentially with different field workers (although ultimately the same team of field workers evaluated all sites). The site evaluation forms consisted of four main sections of questions with several sub-sections:

1) Location and description of the site and its surroundings;
2) Buffer functional considerations, with sub-sections related to
    a) water quality renovation;
    b) wildlife habitat;
    c) base flow maintenance and peak flow attenuation; and
    d) education and aesthetics.
3) Cost considerations, with sub-sections related to
    a) potential buffer restoration components; and
    b) estimated costs and benefits.
4) Practical considerations, both socioeconomic and physical.

In general, the sections related to buffer functional considerations and practical considerations consisted of ratings as to whether particular conditions existed at the site (yes = 1, no = 0). Based on these ratings, each site could be given a total score reflecting its suitability as a restoration site based on the criteria of any sub-section. Both existing and potential conditions were taken into account at each site. The section dealing with cost considerations listed potential actions that might be taken to restore a site, and the evaluators judged whether each action would be part of a minimal or an extensive restoration effort, or whether it was not relevant for that site. Based on these judgments, estimates of likely restoration costs and resulting benefits were also made. Also, several photographs were taken at each site.

Site evaluation field work was done by a two-person crew during the months of October – December, 2000. Overall, forty-six sites were identified in Providence, North Providence, Johnston, Smithfield, and Glocester. From the forty-six sites, thirty-six site evaluation forms were filled out. Of the ten sites for which forms were not completed, two were combined with other sites in the evaluation and the other eight were evaluated as having no restoration opportunity. Three sites were visited only during preliminary reconnaissance. Section 3 (Table 3-1) lists all sites.

2.3 GIS Database

The information on the site evaluation forms was compiled into a Microsoft Access database. One of the tables in the relational database was used to spatially link the existing GIS base data acquired from Rhode Island's RIGIS program. The photographs taken during site evaluations were also hot-linked to the site locations to complete the GIS database. Primary functions of this database include:

1) Searching for all the information on a particular site;
2) Querying for all sites that meet certain criteria;
3) Sorting in terms of restoration suitability according to the criteria of a given sub-section (*e.g.*, water quality renovation) or section (*e.g.*, buffer functional considerations); and
4) Site mapping.

3.0 INVENTORY RESULTS

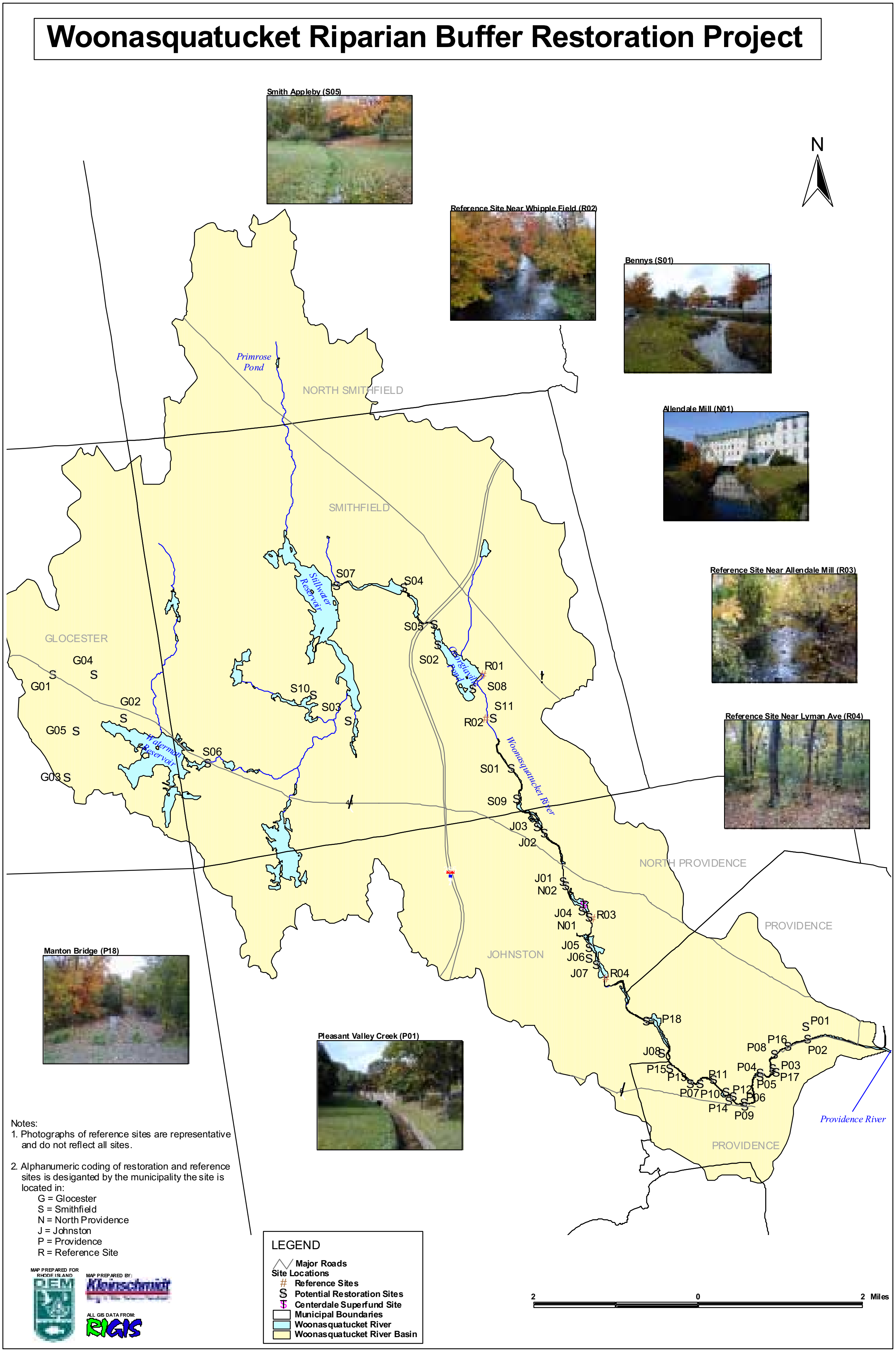
Overview

Only sites that appeared promising to the nominator and/or the Contractor were evaluated. This yielded thirty-six detailed site evaluations. The locations of these thirty-six sites are shown on Figure 3-1 and listed in Table 3-1. Sites are identified by alphanumeric codes where the first letter of the code represents the first letter of the municipality where it is located. Reference sites (*e.g.,* intact riparian forest buffers) begin with an "R". The locations of the Reference sites that were used are also shown on Figure 3-1. Individual site descriptions and rankings are included in Appendix A. Due largely to active stakeholder participation, and to the fact that nominators were very knowledgeable about their watershed, the authors feel that most of the buffer restoration projects with the greatest potential were evaluated.

The sites evaluated were fairly diverse in terms of location in the watershed and existing conditions. Several potential riparian buffer restoration sites occur within tidal influence, below the lowermost dam on the River (Rising Sun Dam): #P01, #P02, #P03, #P04, #P05, #P08, #P16, and #P17. Several potential restoration sites were old mill sites, both defunct and operational, mostly in the lower portion of the watershed: #P02, #P03, #P08, #P10, #P11, #P17, #N01, #S04, and #J02. A few sites are part of other types of industrial and commercial development such as shopping centers, offices, and parking facilities: #P05, #P06, #P09, #P16, and #S01.

A few of the sites are associated with auto salvage yards and sand and gravel mining operations, which are especially prevalent in Johnston: #J04, #J05, #J06, and #J07. The prevalence of mining operations in the watershed results from the outwash overburden (*i.e.*, coarse-textured, water-sorted materials such as sand and gravel) discussed above. Several open space areas, such as parks, building grounds, or DOT properties served as potential restoration sites: #P01, #P04, #P07, #P14, #P15, #J08, #S05, #S06 and #G02. Many of these areas are dominated by managed vegetation and lawn, rather than naturally vegetated buffers. Other types of potential restoration sites include municipal/public works (*e.g.,* site #S03), and residential areas (*e.g.,* site #S02).

Figure 3-1


Woonasquatucket Riparian Buffer Restoration Project
Smith Appleby (S05)
Reference Site Near Whipple Field (R02)
Bennys (S01)
Allendale Mill (N01)
Reference Site Near Allendale Mill (R03)
Reference Site Near Lyman Ave (R04)
Manton Bridge (P18)
Pleasant Valley Creek (P01)
N
Primrose Pond
NORTH SMITHFIELD
SMITHFIELD
GLOCESTER
NORTH PROVIDENCE
JOHNSTON
PROVIDENCE
Stillwater Reservoir
Waterman Reservoir
Woonasquatucket River
Providence River
Notes:
1. Photographs of reference sites are representative and do not reflect all sites.
2. Alphanumeric coding of restoration and reference sites is desigantated by the municipality the site is located in:
G = Glocester
S = Smithfield
N = North Providence
J = Johnston
P = Providence
R = Reference Site
MAP PREPARED FOR RHODE ISLAND
MAP PREPARED BY:
Kleinschmidt
ALL GIS DATA FROM:
RIGIS
LEGEND
Major Roads
Site Locations
Reference Sites
Potential Restoration Sites
Centerdale Superfund Site
Municipal Boundaries
Woonasquatucket River
Woonasquatucket River Basin
2 0 2 Miles

Promising sites were considered to be those that were significantly degraded in the existing condition and which could potentially be modified to restore lost or degraded buffer functions. Virtually every site evaluated lacked forest vegetation that was replaced by mowed lawn, fill, trash, or abandoned impervious surfaces. Other sites included buffers with poorly functioning stormwater systems. This included sites where concentrated runoff carried sediment and pollutants directly to the river (*e.g.,* through paved swales, eroded gullies, or pipes), limiting infiltration into the soils of naturally vegetated cover types. This condition applied to about half of the sites evaluated. Soil erosion, exposed or disturbed soils, or unstable stream banks were also characteristics that indicated promising sites. This condition applied to less than half of the sites evaluated. Sites that have experienced hydrologic alterations, such as drainage diversions or flood regime alterations, that have resulted in degraded buffer functions, may also be promising sites. This situation applied to more than half of the sites evaluated if sites are included where modifications such as floodwalls, fill, or channelization have prevented the River from being more closely linked hydrologically to the riparian buffer (such as floodplains).

For the 36 sites that were evaluated, each was rated for: 1) the opportunity to enhance several ecological and socioeconomic functions; 2) the presence or absence of practical considerations (potential restoration constraints); and 3) estimated costs and benefit/cost ratios. The results of this evaluation are sorted in several different ways below to provide users of this report, who might have wide-ranging objectives and cost constraints, with a tool to identify the best sites under a variety of criteria. For example, the user that is primarily interested in isolating several sites with a high potential to provide functional gains in wildlife habitat and with low associated costs, can determine the best sites in both regards and then determine where there is overlap.

Reference sites were identified and used to establish guidelines for the target conditions. These areas provided useful information on native plant communities in the watershed as well as abiotic conditions such as soils, floodplain dynamics, and topography/microtopography.

Ratings

The tables at the end of this section show the ratings of each site for riparian buffer function indicators, practical considerations, and cost considerations. Buffer functional considerations and cost considerations are further divided into four sub-categories and three sub-categories, respectively. The rating system for buffer functional considerations and practical considerations is normalized on a scale from 0.000 to 1.000 for each category rated, while the rating system for cost considerations uses mostly qualitative assessments, such as "high" or "low".

With regard to the normalized ratings of functional and practical considerations, alternative sites can be rated numerically in comparable units that allow for useful relative comparisons, but these numbers are not absolute and individual questions are not weighted according to relative importance. For example, if a site scores 1.000, this is not necessarily twice as good as 0.500, since the individual questions were not assigned weights, and one question may be more important than another depending on objectives and other variables. However, the questions are thought to represent the most important criteria based on the best current science. So, for example, a high rating, such as 1.000 or 0.800, would indicate that the majority of the identified elements associated with an attractive potential restoration site for the particular category are present, and a low number, such as 0.000 or 0.200, would indicate that most elements are absent.

This rating system typically results in sites being sorted into groups of similar ratings for each particular evaluation category. For example, for water quality, several sites received a 1.000, several received a 0.800, several received a 0.600, etc. This is as a result of the fact that there were five questions with answers of "yes" or "no", and sites received ratings of zero-out-of-five (0.000) through five-out-of-five (1.000). This rating system does not rate sites at a precision that isolates the single best site for a given category because the site evaluation method was developed to be a relatively rapid field evaluation with replicable results under which each indicator question received a "yes" or "no" answer. However, when several different categories are analyzed simultaneously, the site ratings begin to sort into smaller groupings.

Buffer Functions

There are many riparian buffer functions and values. However, this study focused on three broad ecological functions and one non-ecological function that are generally considered to be key buffer functions (Palone and Todd, 1997) and which were considered to be the most important with respect to the objectives of this study and the restoration of the Woonasquatucket River watershed in general. They were:

- Water quality
- Wildlife habitat
- Flood storage
- Education and Aesthetics

Additional functions include groundwater quality and quantity maintenance, recreation, and instream habitat (fish and aquatic macroinvertebrate). Although these functions were not specifically examined, most aspects of these functions were incorporated in the buffer evaluations by default. For example, evaluations of a site's potential for water quality and water quantity functions necessarily incorporate most of the same characteristics that are important for groundwater (*e.g.,* storage and infiltration versus concentrated overland flows and runoff from impervious surfaces). Reforestation efforts associated with water quality and wildlife habitat improvement also directly affect instream habitat components such as coarse woody debris and litter inputs to the stream that are important for aquatic organisms such as fish and aquatic macroinvertebrates.

Water Quality

Riparian buffers provide important water quality functions such as filtering sediments and pollutants from runoff. Properly sized and designed buffers promote infiltration and storage and discourage concentrated runoff while promoting diffuse flows. Since phosphorous and many other pollutants are bound to soil particles, sediment settling and trapping is a critical buffer function. Biogeochemical processes associated with naturally vegetated buffers also promote the retention or conversion of nutrients/pollutants that are in solution. For example, buffers (especially those with saturated, but not inundated soils) promote the process of denitrification whereby biologically available nitrogen is converted to a gaseous form and removed from the system. Another nutrient/pollutant removal mechanism is plant uptake. However, this only results in a net removal to the extent that the system is accumulating biomass (which would be the case for many decades with buffer reforestation efforts), or there is a flux of biomass from the system (such as plant harvesting, more detritus leaving the site than entering). Buffers also maintain instream water quality by keeping water temperatures cool in the summer through shading. Lastly, buffers promote stream bank stabilization, thereby protecting downstream water quality. Note that buffers also provide important groundwater quality and recharge/discharge functions. For example, wetlands that promote infiltration can provide important groundwater quality and quantity effects, and this groundwater may end up ultimately being discharged to the river, thereby affecting surface water quality.

The five buffer characteristics used to indicate that a particular site had potential for restoring or developing an effective water quality function were:

- Concentrated stormwater runoff or point discharges that bypass the buffer without long-term contact with the soil-root zone of the buffer (*e.g.,* eroded gullies, piped drainage, paved swales, or hydrologic alterations that have impacted water quality functions).
- Potential sources of sediment or pollutant loading in the contributing sub-watershed (*e.g.,* surrounding buffer is developed with a high percentage of impervious surfaces as opposed to mostly forested or naturally vegetated).
- Poor vegetation condition or impervious surface (*e.g.,* exposed soils, closely mowed lawn, sparse vegetation resulting from sterile soils, or impervious surface that is abandoned or in disrepair). There is potential to add native buffer vegetation to the buffer where it is currently lacking to improve water quality functions.
- Active soil erosion or unstable stream bank sections in the buffer beyond natural levels (*e.g.,* as a result of disturbance).
- Physical characteristics of the buffer (such as flat topography or hydrologic modification that can be corrected) lend themselves to significant potential improvements in water quality functions such as sediment trapping and infiltration with noted modifications. Desired characteristics that encourage infiltration and diffuse rather than concentrated

runoff include complex microtopography including some slopes away from river or swales, wetlands with a basin configuration or constricted outlet, and a lack of slopes that grade steeply and smoothly to the watercourse. Sites where these characteristics can be reasonably developed are potential restoration sites.

Table 3-2 indicates the relative rankings of the sites for restoration potential specific to the water quality function. Ratings for the other buffer functions are also shown (shaded in gray) in order to provide context for the water quality ratings. Well over half of the sites were evaluated as having a score of 0.800 or 1.000 (*i.e.*, at least four-out-of-five of the restoration opportunity indicators listed above). Nine sites scored a perfect 1.000 (five-out-of-five of the indicators present). The generally high ratings are partly a result of the fact that sites were screened prior to detailed evaluation.

Wildlife Habitat

Plant and wildlife diversity and productivity are often greater in riparian forests than in non-riparian forested systems (Palone and Todd, 1997). A disproportionately high number of wildlife species utilize riparian forests as a preferred habitat. Riparian systems offer a source of perennial drinking water for mammals and birds. The interface of river and forest forms productive edge habitat. Riparian forests can serve as important travel and dispersal corridors for wildlife when they are relatively contiguous, especially in urban or suburban areas where there is a lack of other habitat, or there is excessive fragmentation. Increased light levels, varying topography, varying moisture regimes, and irregular edges between aquatic and terrestrial cover types often enhance the vertical and horizontal complexity of vegetation at the river margin. The structure that develops in a mature riparian forest, including snags, rotten logs, and thick duff layers, is also an important habitat feature that open habitat types do not provide. Juxtapositions between open water and forest are valuable for species such as wood duck that nest in tree cavities near open water, and mammals such as mink that forage along the water's edge.

The four buffer characteristics used to indicate that a particular site had potential for restoring or developing an effective wildlife habitat function were:

- Exotic and/or invasive plant species are present and significantly impact biological functions such as plant and wildlife habitat (*e.g.,* this does not include one or two barberry bushes over a relatively large area, such as an acre, but does include an expanding patch of knotweed or purple loosestrife).
- Buffer is adjacent to naturally vegetated habitat such as forest, wetland, or abandoned field. There is opportunity to improve the overall habitat matrix of the surrounding area by planting trees and other native vegetation in the buffer site to extend or connect existing forested corridors, or enlarge interior habitat patches, or enhance habitat juxtapositions (such as re-planting forest adjacent to a vernal pool or riparian wetland).
- Contiguous instream habitat is relatively high quality. Features such as important fish habitat and/or river-dependent wildlife habitat, or natural stream conditions are present.
- Buffer is degraded by human activity in a way that negatively impacts wildlife habitat and can be corrected (*e.g.,* trash dumping, poorly vegetated condition due to fill material or sterile soil conditions, abandoned or unnecessary impervious surface present).

Table 3-3 indicates the relative rankings of the sites for restoration potential specific to the wildlife habitat function. Ratings for the other buffer functions are also shown (shaded in gray) in order to provide context for the wildlife habitat ratings. More than half of the sites were evaluated as having a score of 0.750 or 1.000 (*i.e*., at least three-out-of-four of the restoration opportunity indicators listed above). Ten sites (or more than one quarter of sites evaluated) scored a perfect 1.000 (four out of four of the indicators present).

Base Flow Maintenance/Peak Flow Attenuation

Riparian buffers provide important water quantity functions. Floodplains accommodate overbank flows and lessen downstream flooding. Non-floodplain portions of riparian buffers also provide a flood desynchronization function by storing stormwater during wet periods and releasing it slowly downstream during dry periods, ensuring an adequate baseflow for aquatic organisms in late summer and attenuating peak flow levels. Forested riparian buffers are associated with higher infiltration rates than open systems (Palone and Todd, 1997). Flood storage in the upper portion of the watershed is more effective than storage in the lower portion of the watershed for promoting a desynchronization function. For example, stormwater that is stored by high elevation wetlands along small headwater streams in the spring, in places like Glocester and North Smithfield, may help maintain baseflow along the main-stem River in Providence in the late summer. Floodwater storage in downtown Providence, immediately adjacent to the main-stem River, however, will do little to desynchronize flows in a beneficial way.

The two buffer characteristics that were used to indicate that a particular site had potential for restoring or developing an effective stream flow regulation function were:

- Buffer occupies upper position in the watershed (*i.e.*, upper part of the river or upper part of the watershed away from the river). Generally upstream from the Smithfield town line or along a tributary stream or away from the river proper.
- Reasonable modifications (as noted) could increase the buffer's ability to store a significant volume of runoff. Characteristics that enhance flood storage capacity include basin configuration, constricted outlet, low gradient topography, and complex topography or high surface roughness such as pit and mound topography. Complex drainage, such as a meandering intermittent stream with large woody debris in it, as opposed to channelized runoff, is better at desynchronizing flows but is not as good as a basin with a constricted outlet. If such characteristics have been degraded/eliminated through human activity in the buffer and can be restored with modifications such as removing impervious surfaces, re-grading, or capturing channelized runoff, there is opportunity to restore/enhance this function.

Note that the cutoffs specified in the first indicator for upper versus lower position in the watershed are fairly arbitrary. The Smithfield town line cutoff is based on best professional judgment rather than specific hydrologic data. However, it is certainly true that sites on the River north of the Smithfield town line serve a more important potential flood storage function than do sites along the River downstream of this cutoff. Therefore, the distinction does result in a relative comparison, just as other indicators.

Table 3-4 indicates the relative rankings of the sites for restoration potential specific to the base flow maintenance/peak flow attenuation function. Ratings for the other buffer functions are also shown (shaded in gray) in order to provide context for the base flow maintenance/peak flow attenuation ratings. More than 20% of the sites were evaluated as having a score of 1.000 (*i.e.*, two-out-of-two of the restoration opportunity indicators listed above).

Education and Aesthetics

Riparian buffers provide important non-ecological functions and values. This study specifically focused on education and aesthetics. Riparian buffers can function as "outdoor classrooms". They can be used for research, and can provide active outdoor learning opportunities for local grade schools and for colleges/universities. Additionally, buffers can provide educational value to the general public through such outreach elements as guided tours and kiosks. Indirectly, education and aesthetic enhancements can enhance other functions, such as water quality maintenance, to the extent that they foster a public appreciation for the natural resources associated with their river and its watershed. Aesthetics is a relatively subjective value, and is usually most related to visual elements, but may also include odor. It is generally true that forested and other naturally vegetated riparian buffers enhance the aesthetic value of a river corridor, particularly in urban and suburban settings where they are visible to many people and provide a contrast to surrounding development.

The four buffer characteristics used to indicate that a particular site had potential for restoring or developing effective education and aesthetic values were:

- Site is visually accessible (*e.g.,* conspicuous for a large number of people).
- Site is physically accessible or potentially accessible to the public by foot, bike, or car (*e.g.,* paths, nearby roads, and nearby parking).
- Site is within 1 mile of a school or densely populated area.
- The adjacent in-stream habitat is relatively natural (*e.g.,* not channelized or highly degraded visually) and there is opportunity to view wildlife, native plant communities and other characteristics of a naturally functioning stream corridor.

Table 3-5 indicates the relative rankings of the sites for restoration potential specific to the education and aesthetics function. Ratings for the other buffer functions are also shown (shaded in gray) in order to provide context for the education and aesthetics ratings. More than half of the sites were evaluated as having a score of 0.750 or 1.000 (*i.e.*, at least three-out-of-four of the restoration opportunity indicators listed above). Ten sites (or more than 20% of sites evaluated) scored a perfect 1.000 (four-out-of-four of the indicators present).

Overall Ecological

Table 3-6 shows the relative rankings of the sites for restoration potential as the straight average (*i.e.*, equal weighting) of the three ecological functions (*i.e.*, water quality, wildlife habitat, and base flow maintenance/peak flow attenuation). Ratings for the individual buffer functions (including non-ecological) are also shown (shaded in gray) in order to provide context for the overall ecological ratings. The reader is advised that the individual functions and the component parts within individual functions were not weighted according to estimated relative importance. The individual user, however, can take the data and weight component parts according their own needs and objectives. It was thought that an unweighted average would provide one means of identifying those sites that are well rounded or have an overall potential to provide a suite of functions. As seen in the table, this averaging succeeds in sorting out the sites from each other in the relative ranking order. Specifically, the rankings are not clustered into groups of identical values and in fact have a wide range (between 0.917 and 0.150) with a relatively even distribution through that range. Although this ecological rating is somewhat arbitrary in its weighting of indicators within functions or individual functions, it demonstrates that the use of more evaluation categories to rate alternative sites yields greater differentiation of the sites from one another.

Practical Considerations

Practical considerations were considered important since a site that has tremendous potential for the restoration of desired buffer functions may turn out not to be a viable restoration opportunity if there are other limiting factors. The best potential sites are those where the land is either publicly owned or the private owner wishes to donate the site, sell it reasonably, or restore it and place it into a permanent conservation easement. The best sites also lack practical socioeconomic constraints (*e.g.,* regulatory hurdles, or community opposition) and physical/geologic site constraints (such as the presence of ROWs, lack of access, or steep and ledgy soils) that would limit or preclude project restoration.

The eight factors used to indicate that a particular site lacked potential limiting practical constraints, or conversely that there were positive practical considerations that would affect its attractiveness for restoration, were:

- Ownership is public, or private owner has stated a willingness to donate or sell the property reasonably.
- Site restoration could be accomplished relatively quickly assuming financial resources available. There are no known obvious impediments that could complicate implementation such as active land uses that would need to be relocated, multiple landowners, unusually complicated permitting issues, or known opposition.
- High potential for partnering with an interested organization or individual that would support the project, including potential financial or in-kind service support.
- There appear to be no obvious ROW issues such as buried cable, utility ROWs, railroad tracks, etc. that would interfere with site restoration.
- There are no reasons to suspect that soils may be contaminated (such as abandoned industrial use, odors, visible oil slicks, metal drums, transformers, etc.). This would be true of Superfund sites only after clean-up is complete.
- There is good existing access for people and equipment or it appears such access could be easily created.
- There are no topographic or geologic constraints to site restoration such as steep slopes, or shallow-to-bedrock soils.
- There are no known endangered species issues or cultural resource issues at this site.

Additional factors could be identified on a site-specific basis, but the factors listed above generally encompassed the potential practical limiting factors for the sites we evaluated. Table 3-7 indicates the relative rankings of the sites with regard to practical considerations. Ratings for the four buffer functions are also shown (shaded in gray) in order to provide context for the practical considerations ratings.

Overall Composite

Table 3-8 shows the relative rankings of the sites for restoration potential as the straight average (*i.e.*, equal weighting) of all three ecological functions, the single socioeconomic function, and practical considerations (*i.e.*, water quality, wildlife habitat, base flow maintenance/peak flow attenuation, education/aesthetics, and practical considerations). See the section on overall ecological ratings for more discussion of this method of presentation. The range of numerical rankings was between 0.850 and 0.290.

Cost Considerations

Estimates were made at each site of restoration cost, ratio of restoration benefit to restoration cost, and risk of restoration failure.

Restoration Cost

For each site, the costs of implementing the envisioned restoration design was estimated. For many sites both a less extensive and a more extensive restoration option were evaluated. For example, a site's less extensive opportunity (option #1) might be to simply stop mowing or to install native buffer plantings. For the same site, the more extensive option (option #2) might additionally involve more ambitious restoration components such as impervious surface removal, grading, exotic/invasive species eradication, biostabilization of banks, or stream channel relocation.

The costs were roughly classified into four categories: low cost ($0-$15,000), moderate cost ($15,000-$50,000), high cost ($50,000-$100,000), and very high cost (> $100,000). A fifth category ("flexible") was used to indicate that any cost category could apply. For example, it is possible to develop aspects of buffer restoration with low costs if only the simplest aspects of restoration are implemented, such as planting only, but high costs are possible if other components, such as grading or impervious surface removal, are implemented. However, if a site is covered with impervious surfaces and has a floodwall, there may not be any low cost alternatives (unless the costs are picked up by the landowner or another entity).

The cost estimates do not include land acquisition, permitting, Phase I environmental analyses, or soil testing for contamination, nor do they include costs associated with an educational component. They do include design/build costs. As a tool to estimate costs, a checklist containing the following items was used to indicate restoration components:

- Installation of native buffer plantings (including trees, groundcover seeding, etc.)
- Removal/eradication of exotic/invasive species
- Soil amendments (*e.g.,* addition of topsoil)
- Soil removal (*e.g.,* fill removal)
- Bank stabilization - biostabilization (such as wattles, cuttings, and minor soil work/erosion control fabric)
- Bank stabilization - structural (*e.g.,* planted gabions, cribs)
- Floodwall or retaining wall removal
- Soil stabilization/erosion control during construction (*e.g.,* silt fence, mulching and seeding)
- Minor grading to enhance infiltration, storage, floodplain functions, or habitat
- Major grading to enhance infiltration, storage, floodplain functions, or habitat
- Impervious surface removal (specify whether structure, asphalt, etc.)
- Remove/modify concentrated runoff (ditch, paved swale, etc.)
- Construct stormwater management measure (*e.g.,* settling basin/biofilter basin, level spreader, velocity dissipater, etc.)
- Construct access (*e.g.,* for people as well as equipment during restoration) if none exists
- Trash removal (*e.g.,* old cars, tires, etc.)

Work in the stream channel (*e.g.,* channel relocation, revetments, rock placements, etc.) was generally not the focus of this study, which was generally buffer-oriented. However, there were several sites where there was good potential to modify the stream channel to enhance habitat and water quality functions, and these were noted.

The cost estimates assume that projects will entail help from consultants (design, oversight, bid, implementation, and limited monitoring). Not all projects need be intricate or costly, however, and some might include volunteer labor, donated or discounted materials, and/or simple measures such as plantings. Most of the "very high" estimates resulted from retaining wall and impervious surface removal and subsequent major grading and bank stabilization.

Importantly, this level of costing is very useful for site selection, but once a site is actually chosen a more detailed cost estimate should be completed.

Tables 3-9 and 3-10 show the relative rankings of the sites according to estimated costs for the less extensive (#1) and more extensive (#2) options, respectively. Estimates of benefit/cost ratio and risk of failure are also shown (shaded in gray) in order to provide context for the cost estimates.

Benefit/Cost Ratio

Benefit/cost analysis is key to ranking alternative restoration sites, as well as alternative restoration designs for a single site. The restoration site/alternative with the greatest ecological benefit is not necessarily the best option. The level of restoration can be increased up to the point when the benefits are no longer estimated to outweigh the costs (FISRWG, 1998). A restoration design is less than optimal if the same level of gain could be achieved by another alternative at less cost. Since planting is so cheap relative to other more involved measures, plant installations often have high benefit/cost ratios. More involved projects that include measures such as floodwall removal, major grading, and streambank stabilization measures have greater benefits, but the costs are much higher. Restorations involving the correction of simple hydrologic modifications often have very high benefit/cost ratios. For example, if a large streamside wetland is still intact and at proper grade, but has been starved of hydrologic inputs because of drainage that is piped around the site or blocked by a levee, fairly low-cost measures could return the system to one yielding much greater benefits in terms of functions and values. Areas that are mowed lawn to the river/stream edge are another example of sites that typically have a very high benefit/cost ratio.

A qualitative estimate of the ratio of restoration benefit (*e.g.,* the gain in wetland functions and values) to estimated restoration costs was completed for each site. One of the following categories was selected based on best professional judgment in the field using the functional ratings and estimated costs as the primary guide:

- Ratio is very high (*e.g.,* significant functional gain with little cost/effort).
- Ratio is moderately high (*e.g.,* significant functional gain with moderate cost/effort, or moderate functional gain with little cost/effort).
- Ratio is approximately even (*e.g.,* significant functional gain with significant cost/effort, moderate functional gain with moderate cost/effort, or little functional gain with little cost/effort).
- Ratio is moderately low (moderate functional gain with significant cost/effort, or little functional gain with moderate cost/effort).
- Ratio is very low (little functional gain with significant cost/effort).

Tables 3-11 and 3-12 show the relative rankings of the sites according to estimated benefit/cost ratios for the less extensive (#1) and more extensive (#2) options, respectively. Estimates of restoration cost and risk of failure are also shown (shaded in gray) in order to provide context for the benefit/cost ratio estimates.

Risk of Failure

The risk of restoration failure was assessed for each site. The level of risk that restoration objectives might not be achieved because of unexpected problems with restoration design, physical site characteristics, or environmental variables was considered an important factor to assess. Site designs that may involve an elevated risk of failure include, but are not limited to, designs that involve work on the stream bank, work on steep slopes, work on erodible soils, removal of impervious surfaces, or work in abandoned industrial zones (where soils may be contaminated). An assessment of a high level of risk should not preclude attempts at restoration since many very good restoration designs involve some level of risk and many of these risks can be overcome with proper resources. Most failures can be corrected, but there is an associated cost and environmental impact. The following categories were used:

- Risk is very high (estimated >25% chance of failure in at least one significant restoration component).
- Risk is moderately high (estimated 10-25% chance of failure in at least one significant restoration component).
- Risk is moderately low (estimated 2-10% chance of failure in at least one significant restoration component).
- Risk is very low (estimated <2% chance of failure in at least one significant restoration component).

Tables 3-13 and 3-14 show the relative rankings of the sites according to estimated risk of failure for the less extensive (#1) and more extensive (#2) options, respectively. Estimates of restoration cost and benefit/cost ratio are also shown (shaded in gray) in order to provide context for the risk of failure estimates.

Table 3-1. Site Summary.

Site I.D.#	Describe	Town	Ownership	Owned by	Source (a), (b)
G01	Cuttler Brook at Jug Handle (Farnum Rd./Rt. 44)	Glocester	Public		Glocester
G02	Glocester Country Club (Melody Hill Golf Course)	Glocester	Private		Glocester
G03	Byron Winsor Park	Glocester	Public		Glocester
G04	Cuttler Brook at cranberry bog (Cooper Rd./Farnum Rd./Rt. 44)	Glocester	Private		Glocester
G05	Cuttler Brook at Waterman's Reservoir (Snake Hill Rd.)	Glocester	Unknown		Glocester
J01	easement near Putnam Pike (Rt. 44)	Johnston	Unknown		NRCS(9)
J02	Greystone Mill parking	Johnston	Private		Audubon; DEM; WRWC-1
J03	Riverside Ave./Angell St. ballpark and playground	Johnston	Public		Field
J04	Libutti Sand and Gravel (100 Allendale Ave.)	Johnston	Private		WRWC-1; NRCS(10)
J05	New England Sand and Gravel (100 Armento St.)	Johnston	Private		WRWC-1; NRCS(12)
J06	Johnston Auto Salvage	Johnston	Private		WRWC-1
J07	Pezza Sand and Gravel (100 Irons Ave.)	Johnston	Private		WRWC-1; NRCS(11)
J08	Dyerville Park golf course	Johnston	Public		DEM; WRWC-1; NRCS(13)
N01	Allendale Mill	N. Providence	Private		DEM; WRWC-1
N02	Centredale Manor	N. Providence	Private		Field
P01	Pleasant Valley Creek / VA Med. Center	Providence	Public		DEM
P02	68 Hemlock St.	Providence	Private	Jacob Licht, Inc.	NRCS(8)
P03	586 Atwells Ave.	Providence	Private	General Electric Co.	NRCS(6)
P04	Valley St./Cutler St. playground	Providence	Public	City of Providence	DEM
P05	190 Valley St.	Providence	Private	William Rodi	NRCS (4)
P06	80 Manton Ave. (shopping center)	Providence	Private	Multiple (Price Rite)	Field
P07	Merino Park	Providence	Public	City of Providence	DEM
P08	Eagle St./Atwells Ave./Valley St. Brownfield	Providence	Private	(formerly Uncas Manufacturing, Robin Motta, Robert Resnick, Sterling Properties)	DEM; WRWC-1 (E-4)?
P09	Olneyville post office parking	Providence	Public		NRCS(3)
P10	Riverside Mill (50 Aleppo St.)	Providence	Public	City of Providence (formerly Lewis Barry)	WRWC-1 (A-1); NRCS(1)
P11	120 Aleppo St.	Providence	Private	Thomas Deconcilis	WRWC-1 (A-4); NRCS(2)
P12	Atlantic Mills (Manton Ave.)	Providence	Private	Martin Braver Trust, Rhode Island Mill Co.	WRWC-1
P13	Lincoln Lace and Braid Brownfield (near Merino Park)	Providence	Private	Ponagansett Realty, Pace Enterprises	WRWC-1
P14	Hartford Ave./Rt. 6 DOT site	Providence	Public	Department of Transportation	WRWT-2
P15	Mancini Dr. tributary	Providence	Public		WRWT-2
P16	411 Valley St.	Providence	Private	Licht Family Realty	NRCS(7)
P17	537 Harris Ave.	Providence	Private	General Electric Co.	NRCS(5)
P18	Stop-N-Shop (near Manton Ave. bridge)	Providence	Private		DEM
S01	Benny's warehouse (Waterman Ave.)	Smithfield	Private		Audubon; WRWC-1; DEM
S02	Farnum Heights (Lakeside Dr.)	Smithfield	Private		Smithfield
S03	Smithfield Public Works (3 Spragueville Rd.)	Smithfield	Public		Smithfield
S04	Stillwater Mill (Stillwater Rd./Thurber Ave.)	Smithfield	Private		DEM
S05	Smith Appleby (Stillwater Rd.)	Smithfield	Public		DEM
S06	Rt. 44/ W. Greenville Rd. DOT site	Smithfield	Public	Department of Transportation	Glocester
S07	bridge construction (Rt. 104/Rt. 116)	Smithfield	Public		Audubon; DEM
S08	Georgiaville Beach	Smithfield	Public		DEM
S09	Smithfield Treatment Plant (Esmond Mill Pond)	Smithfield	Public		DEM
S10	South Branch	Smithfield	Unknown		Audubon
S11	Whipple Field	Smithfield	Public		DEM

(a) Source identifying site: Audubon - Audubon Society (11/17/00); DEM - Rhode Island Department of Environmental Management site tour (10/17/00); Field - Field visit (11/19/00, 11/20/00, 11/21/00); Glocester - Town of Glocester (11/8/00); WRWC-1 - Woonasquatucket River Greenway; NRCS - Natural Resources Conservation Service (11/17/00); Smithfield - Town of Smithfield (11/21/00); WRWT-2 - Woonasquatucket River Watershed Team (12/5/00)

(b) Woonasquatucket River Watershed Council/Woonasquatucket River Greenway: A-Acquisition Priority; E-Easement Priority

Table 3-2. Site rankings for water quality function.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics
J05	1.000	0.750	0.500	0.250
J07	1.000	0.500	0.500	0.250
N01	1.000	1.000	0.500	1.000
P02	1.000	0.500	0.000	0.750
P08	1.000	0.750	0.500	1.000
P16	1.000	0.500	0.000	0.750
P18	1.000	0.750	0.000	0.750
S05	1.000	0.750	1.000	0.750
S06	1.000	0.250	1.000	0.500
G01	0.800	0.750	1.000	0.750
J02	0.800	0.500	0.500	0.750
J04	0.800	1.000	0.500	0.500
J06	0.800	0.750	0.500	0.250
J08	0.800	1.000	0.000	1.000
P03	0.800	0.500	0.500	0.500
P04	0.800	1.000	0.000	1.000
P05	0.800	0.750	0.500	1.000
P06	0.800	0.500	0.500	0.750
P09	0.800	0.500	0.500	0.750
P12	0.800	0.500	0.500	0.750
P13	0.800	1.000	0.500	1.000
P17	0.800	0.500	0.500	0.500
S01	0.800	0.750	1.000	1.000
S02	0.800	0.500	1.000	0.250
G02	0.600	0.250	1.000	0.250
J03	0.600	0.750	0.000	1.000
N02	0.600	0.500	0.500	0.750
P01	0.600	0.750	0.500	0.750
P10	0.600	1.000	0.500	0.750
S03	0.600	1.000	1.000	0.750
P07	0.400	1.000	0.000	1.000
P15	0.400	1.000	0.000	0.750
S04	0.400	1.000	1.000	0.500
J01	0.200	0.250	0.000	0.500
P11	0.200	0.750	0.000	1.000
P14	0.200	0.750	0.000	0.500

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

Table 3-3. Site rankings for wildlife habitat function.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics
J04	0.800	1.000	0.500	0.500
J08	0.800	1.000	0.000	1.000
N01	1.000	1.000	0.500	1.000
P04	0.800	1.000	0.000	1.000
P07	0.400	1.000	0.000	1.000
P10	0.600	1.000	0.500	0.750
P13	0.800	1.000	0.500	1.000
P15	0.400	1.000	0.000	0.750
S03	0.600	1.000	1.000	0.750
S04	0.400	1.000	1.000	0.500
G01	0.800	0.750	1.000	0.750
J03	0.600	0.750	0.000	1.000
J05	1.000	0.750	0.500	0.250
J06	0.800	0.750	0.500	0.250
P01	0.600	0.750	0.500	0.750
P05	0.800	0.750	0.500	1.000
P08	1.000	0.750	0.500	1.000
P11	0.200	0.750	0.000	1.000
P14	0.200	0.750	0.000	0.500
P18	1.000	0.750	0.000	0.750
S01	0.800	0.750	1.000	1.000
S05	1.000	0.750	1.000	0.750
J02	0.800	0.500	0.500	0.750
J07	1.000	0.500	0.500	0.250
N02	0.600	0.500	0.500	0.750
P02	1.000	0.500	0.000	0.750
P03	0.800	0.500	0.500	0.500
P06	0.800	0.500	0.500	0.750
P09	0.800	0.500	0.500	0.750
P12	0.800	0.500	0.500	0.750
P16	1.000	0.500	0.000	0.750
P17	0.800	0.500	0.500	0.500
S02	0.800	0.500	1.000	0.250
G02	0.600	0.250	1.000	0.250
J01	0.200	0.250	0.000	0.500
S06	1.000	0.250	1.000	0.500

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

Table 3-4. Site rankings for base flow maintenance/peak flow attenuation function.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics
G01	0.800	0.750	1.000	0.750
G02	0.600	0.250	1.000	0.250
S01	0.800	0.750	1.000	1.000
S02	0.800	0.500	1.000	0.250
S03	0.600	1.000	1.000	0.750
S04	0.400	1.000	1.000	0.500
S05	1.000	0.750	1.000	0.750
S06	1.000	0.250	1.000	0.500
J02	0.800	0.500	0.500	0.750
J04	0.800	1.000	0.500	0.500
J05	1.000	0.750	0.500	0.250
J06	0.800	0.750	0.500	0.250
J07	1.000	0.500	0.500	0.250
N01	1.000	1.000	0.500	1.000
N02	0.600	0.500	0.500	0.750
P01	0.600	0.750	0.500	0.750
P03	0.800	0.500	0.500	0.500
P05	0.800	0.750	0.500	1.000
P06	0.800	0.500	0.500	0.750
P08	1.000	0.750	0.500	1.000
P09	0.800	0.500	0.500	0.750
P10	0.600	1.000	0.500	0.750
P12	0.800	0.500	0.500	0.750
P13	0.800	1.000	0.500	1.000
P17	0.800	0.500	0.500	0.500
J01	0.200	0.250	0.000	0.500
J03	0.600	0.750	0.000	1.000
J08	0.800	1.000	0.000	1.000
P02	1.000	0.500	0.000	0.750
P04	0.800	1.000	0.000	1.000
P07	0.400	1.000	0.000	1.000
P11	0.200	0.750	0.000	1.000
P14	0.200	0.750	0.000	0.500
P15	0.400	1.000	0.000	0.750
P16	1.000	0.500	0.000	0.750
P18	1.000	0.750	0.000	0.750

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

Table 3-5. Site rankings for education and aesthetics function.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics
J03	0.600	0.750	0.000	1.000
J08	0.800	1.000	0.000	1.000
N01	1.000	1.000	0.500	1.000
P04	0.800	1.000	0.000	1.000
P05	0.800	0.750	0.500	1.000
P07	0.400	1.000	0.000	1.000
P08	1.000	0.750	0.500	1.000
P11	0.200	0.750	0.000	1.000
P13	0.800	1.000	0.500	1.000
S01	0.800	0.750	1.000	1.000
G01	0.800	0.750	1.000	0.750
J02	0.800	0.500	0.500	0.750
N02	0.600	0.500	0.500	0.750
P01	0.600	0.750	0.500	0.750
P02	1.000	0.500	0.000	0.750
P06	0.800	0.500	0.500	0.750
P09	0.800	0.500	0.500	0.750
P10	0.600	1.000	0.500	0.750
P12	0.800	0.500	0.500	0.750
P15	0.400	1.000	0.000	0.750
P16	1.000	0.500	0.000	0.750
P18	1.000	0.750	0.000	0.750
S03	0.600	1.000	1.000	0.750
S05	1.000	0.750	1.000	0.750
J01	0.200	0.250	0.000	0.500
J04	0.800	1.000	0.500	0.500
P03	0.800	0.500	0.500	0.500
P14	0.200	0.750	0.000	0.500
P17	0.800	0.500	0.500	0.500
S04	0.400	1.000	1.000	0.500
S06	1.000	0.250	1.000	0.500
G02	0.600	0.250	1.000	0.250
J05	1.000	0.750	0.500	0.250
J06	0.800	0.750	0.500	0.250
J07	1.000	0.500	0.500	0.250
S02	0.800	0.500	1.000	0.250

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

Table 3-6. Site rankings for overall ecological function.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Overall Ecological[2]
S05	1.000	0.750	1.000	0.917
S03	0.600	1.000	1.000	0.867
G01	0.800	0.750	1.000	0.850
S01	0.800	0.750	1.000	0.850
N01	1.000	1.000	0.500	0.833
S04	0.400	1.000	1.000	0.800
J04	0.800	1.000	0.500	0.767
P13	0.800	1.000	0.500	0.767
S02	0.800	0.500	1.000	0.767
J05	1.000	0.750	0.500	0.750
P08	1.000	0.750	0.500	0.750
S06	1.000	0.250	1.000	0.750
P10	0.600	1.000	0.500	0.700
J06	0.800	0.750	0.500	0.683
P05	0.800	0.750	0.500	0.683
J07	1.000	0.500	0.500	0.667
G02	0.600	0.250	1.000	0.617
P01	0.600	0.750	0.500	0.617
J02	0.800	0.500	0.500	0.600
J08	0.800	1.000	0.000	0.600
P03	0.800	0.500	0.500	0.600
P04	0.800	1.000	0.000	0.600
P06	0.800	0.500	0.500	0.600
P09	0.800	0.500	0.500	0.600
P12	0.800	0.500	0.500	0.600
P17	0.800	0.500	0.500	0.600
P18	1.000	0.750	0.000	0.583
N02	0.600	0.500	0.500	0.533
P02	1.000	0.500	0.000	0.500
P16	1.000	0.500	0.000	0.500
P07	0.400	1.000	0.000	0.467
P15	0.400	1.000	0.000	0.467
J03	0.600	0.750	0.000	0.450
P11	0.200	0.750	0.000	0.317
P14	0.200	0.750	0.000	0.317
J01	0.200	0.250	0.000	0.150

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; and base flow/peak flow, two. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

2) Overall ecological rating based on average of water quality, wildlife habitat, and base flow/peak flow ratings, weighted equally.

Table 3-7. Site rankings for practical considerations.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics	Practical
P01	0.600	0.750	0.500	0.750	1.000
P07	0.400	1.000	0.000	1.000	1.000
P09	0.800	0.500	0.500	0.750	1.000
P10	0.600	1.000	0.500	0.750	1.000
G01	0.800	0.750	1.000	0.750	0.875
J03	0.600	0.750	0.000	1.000	0.875
P13	0.800	1.000	0.500	1.000	0.875
S03	0.600	1.000	1.000	0.750	0.875
J04	0.800	1.000	0.500	0.500	0.750
J08	0.800	1.000	0.000	1.000	0.750
N02	0.600	0.500	0.500	0.750	0.750
P04	0.800	1.000	0.000	1.000	0.750
P11	0.200	0.750	0.000	1.000	0.750
P14	0.200	0.750	0.000	0.500	0.750
P18	1.000	0.750	0.000	0.750	0.750
S05	1.000	0.750	1.000	0.750	0.750
S06	1.000	0.250	1.000	0.500	0.750
G02	0.600	0.250	1.000	0.250	0.625
J02	0.800	0.500	0.500	0.750	0.625
N01	1.000	1.000	0.500	1.000	0.625
P08	1.000	0.750	0.500	1.000	0.625
S04	0.400	1.000	1.000	0.500	0.625
J01	0.200	0.250	0.000	0.500	0.500
P02	1.000	0.500	0.000	0.750	0.500
P03	0.800	0.500	0.500	0.500	0.500
P05	0.800	0.750	0.500	1.000	0.500
P06	0.800	0.500	0.500	0.750	0.500
P12	0.800	0.500	0.500	0.750	0.500
P16	1.000	0.500	0.000	0.750	0.500
P17	0.800	0.500	0.500	0.500	0.500
S01	0.800	0.750	1.000	1.000	0.500
S02	0.800	0.500	1.000	0.250	0.500
J05	1.000	0.750	0.500	0.250	0.375
J06	0.800	0.750	0.500	0.250	0.375
J07	1.000	0.500	0.500	0.250	0.375
P15	0.400	1.000	0.000	0.750	0.375

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

Table 3-8. Site rankings for overall composite.

Site ID	Water Quality	Wildlife Habitat	Base Flow/ Peak Flow	Education/ Aesthetics	Practical	Overall
S05	1.000	0.750	1.000	0.750	0.750	0.850
S03	0.600	1.000	1.000	0.750	0.875	0.845
G01	0.800	0.750	1.000	0.750	0.875	0.835
P13	0.800	1.000	0.500	1.000	0.875	0.835
N01	1.000	1.000	0.500	1.000	0.625	0.825
S01	0.800	0.750	1.000	1.000	0.500	0.810
P08	1.000	0.750	0.500	1.000	0.625	0.775
P10	0.600	1.000	0.500	0.750	0.625	0.770
P01	0.600	0.750	0.500	0.750	1.000	0.720
J04	0.800	1.000	0.500	0.500	0.750	0.710
J08	0.800	1.000	0.000	1.000	0.750	0.710
P04	0.800	1.000	0.000	1.000	0.750	0.710
P05	0.800	0.750	0.500	1.000	0.500	0.710
P09	0.800	0.500	0.500	0.750	1.000	0.710
S04	0.400	1.000	1.000	0.500	0.625	0.705
S06	1.000	0.250	1.000	0.500	0.750	0.700
P07	0.400	1.000	0.000	1.000	1.000	0.680
P18	1.000	0.750	0.000	0.750	0.750	0.650
J03	0.600	0.750	0.000	1.000	0.875	0.645
J02	0.800	0.500	0.500	0.750	0.625	0.635
N02	0.600	0.500	0.500	0.750	0.750	0.620
P06	0.800	0.500	0.500	0.750	0.500	0.610
P12	0.800	0.500	0.500	0.750	0.500	0.610
S02	0.800	0.500	1.000	0.250	0.500	0.610
J05	1.000	0.750	0.500	0.250	0.375	0.575
P03	0.800	0.500	0.500	0.500	0.500	0.560
P17	0.800	0.500	0.500	0.500	0.500	0.560
P02	1.000	0.500	0.000	0.750	0.500	0.550
P16	1.000	0.500	0.000	0.750	0.500	0.550
G02	0.600	0.250	1.000	0.250	0.625	0.545
P11	0.200	0.750	0.000	1.000	0.750	0.540
J06	0.800	0.750	0.500	0.250	0.375	0.535
J07	1.000	0.500	0.500	0.250	0.375	0.525
P15	0.400	1.000	0.000	0.750	0.375	0.505
P14	0.200	0.750	0.000	0.500	0.750	0.440
J01	0.200	0.250	0.000	0.500	0.500	0.290

Notes: 1) Ratings normalized, representing portion of maximum possible rating. Maximum ratings: water quality, five; wildlife habitat, four; base flow/peak flow, two; education/aesthetics, four; and socioeconomic/physical, eight. For example, a water quality rating of three (out of five) would yield a normalized rating of 0.600, whereas a wildlife habitat rating of three (out of four) would yield a normalized rating of 0.750.

2) Overall rating based on average of water quality, wildlife habitat, base flow/peak flow, education/aesthetics, and socioeconomic/physical normalized ratings, weighted equally.

Table 3-9. Estimated restoration costs for option #1 (less extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
P11	flexible	moderately low	very low
G01	low	approximately even	very low
G02	low	moderately high	very low
J01	low	very low	very low
J03	low	very high	very low
J04	low	moderately high	very low
J05	low	moderately high	very low
J06	low	moderately high	very low
J07	low	moderately high	very low
J08	low	moderately high	very low
N01	low	very high	very low
N02	low	moderately high	very low
P01	low	very high	very low
P04	low	moderately high	very low
P07	low	moderately high	very low
P10	low	approximately even	moderately low
P14	low	very low	moderately low
P18	low	approximately even	very low
S01	low	approximately even	very low
S02	low	moderately low	very low
S03	low	approximately even	very low
S04	low	moderately low	moderately low
S05	low	approximately even	very low
S06	low	approximately even	very low
P12	moderate	approximately even	moderately high
P13	moderate	very high	moderately high
P08	high	approximately even	very high
J02	-	-	-
P02	-	-	-
P03	-	-	-
P05	-	-	-
P06	-	-	-
P09	-	-	-
P15	-	-	-
P16	-	-	-
P17	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "less extensive" option (#1) identified and only a "more extensive" option (#2) was evaluated.

Table 3-10. Estimated development costs for option #2 (more extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
P11	low	moderately low	very low
G01	moderate	moderately high	very low
G02	moderate	moderately high	very low
J03	moderate	moderately high	moderately low
J06	moderate	moderately high	moderately low
J08	moderate	approximately even	very low
P01	moderate	moderately low	moderately low
P07	moderate	approximately even	very low
S01	moderate	moderately high	moderately low
S03	moderate	moderately high	moderately low
S05	moderate	moderately high	moderately low
S06	moderate	moderately high	moderately low
J02	high	moderately high	moderately high
N01	high	moderately high	moderately low
P04	high	moderately high	moderately low
P06	high	approximately even	moderately high
P09	high	approximately even	moderately low
P10	high	approximately even	moderately high
P13	high	very high	moderately high
P15	high	moderately low	moderately high
S02	high	approximately even	moderately low
S04	high	moderately low	moderately high
N02	very high	moderately low	moderately high
P02	very high	very low	very high
P03	very high	approximately even	very high
P05	very high	approximately even	very high
P08	very high	approximately even	very high
P12	very high	approximately even	very high
P16	very high	very low	very high
P17	very high	approximately even	very high
J01	-	-	-
J04	-	-	-
J05	-	-	-
J07	-	-	-
P14	-	-	-
P18	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "more extensive" option (#2) identified and only a "less extensive" option (#1) was evaluated.

Table 3-11. Estimated benefit/cost ratio for option #1 (less extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
J03	low	very high	very low
N01	low	very high	very low
P01	low	very high	very low
P13	moderate	very high	moderately high
G02	low	moderately high	very low
J04	low	moderately high	very low
J05	low	moderately high	very low
J06	low	moderately high	very low
J07	low	moderately high	very low
J08	low	moderately high	very low
N02	low	moderately high	very low
P04	low	moderately high	very low
P07	low	moderately high	very low
G01	low	approximately even	very low
P08	high	approximately even	very high
P10	low	approximately even	moderately low
P12	moderate	approximately even	moderately high
P18	low	approximately even	very low
S01	low	approximately even	very low
S03	low	approximately even	very low
S05	low	approximately even	very low
S06	low	approximately even	very low
P11	flexible	moderately low	very low
S02	low	moderately low	very low
S04	low	moderately low	moderately low
J01	low	very low	very low
P14	low	very low	moderately low
J02	-	-	-
P02	-	-	-
P03	-	-	-
P05	-	-	-
P06	-	-	-
P09	-	-	-
P15	-	-	-
P16	-	-	-
P17	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "less extensive" option (#1) identified and only a "more extensive" option (#2) was evaluated.

Table 3-12. Estimated benefit/cost ratio for option #2 (more extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
P13	high	very high	moderately high
G01	moderate	moderately high	very low
G02	moderate	moderately high	very low
J02	high	moderately high	moderately high
J03	moderate	moderately high	moderately low
J06	moderate	moderately high	moderately low
N01	high	moderately high	moderately low
P04	high	moderately high	moderately low
S01	moderate	moderately high	moderately low
S03	moderate	moderately high	moderately low
S05	moderate	moderately high	moderately low
S06	moderate	moderately high	moderately low
J08	moderate	approximately even	very low
P03	very high	approximately even	very high
P05	very high	approximately even	very high
P06	high	approximately even	moderately high
P07	moderate	approximately even	very low
P08	very high	approximately even	very high
P09	high	approximately even	moderately low
P10	high	approximately even	moderately high
P12	very high	approximately even	very high
P17	very high	approximately even	very high
S02	high	approximately even	moderately low
N02	very high	moderately low	moderately high
P01	moderate	moderately low	moderately low
P11	low	moderately low	very low
P15	high	moderately low	moderately high
S04	high	moderately low	moderately high
P02	very high	very low	very high
P16	very high	very low	very high
J01	-	-	-
J04	-	-	-
J05	-	-	-
J07	-	-	-
P14	-	-	-
P18	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "more extensive" option (#2) identified and only a "less extensive" option (#1) was evaluated.

Table 3-13. Estimated risk of failure for option #1 (less extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
G01	low	approximately even	very low
G02	low	moderately high	very low
J01	low	very low	very low
J03	low	very high	very low
J04	low	moderately high	very low
J05	low	moderately high	very low
J06	low	moderately high	very low
J07	low	moderately high	very low
J08	low	moderately high	very low
N01	low	very high	very low
N02	low	moderately high	very low
P01	low	very high	very low
P04	low	moderately high	very low
P07	low	moderately high	very low
P11	flexible	moderately low	very low
P18	low	approximately even	very low
S01	low	approximately even	very low
S02	low	moderately low	very low
S03	low	approximately even	very low
S05	low	approximately even	very low
S06	low	approximately even	very low
P10	low	approximately even	moderately low
P14	low	very low	moderately low
S04	low	moderately low	moderately low
P12	moderate	approximately even	moderately high
P13	moderate	very high	moderately high
P08	high	approximately even	very high
J02	-	-	-
P02	-	-	-
P03	-	-	-
P05	-	-	-
P06	-	-	-
P09	-	-	-
P15	-	-	-
P16	-	-	-
P17	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "less extensive" option (#1) identified and only a "more extensive" option (#2) was evaluated.

Table 3-14. Estimated risk of failure for option #2 (more extensive).

Site ID	Cost	Benefit/Cost Ratio	Risk of Failure
G01	moderate	moderately high	very low
G02	moderate	moderately high	very low
J08	moderate	approximately even	very low
P07	moderate	approximately even	very low
P11	low	moderately low	very low
J03	moderate	moderately high	moderately low
J06	moderate	moderately high	moderately low
N01	high	moderately high	moderately low
P01	moderate	moderately low	moderately low
P04	high	moderately high	moderately low
P09	high	approximately even	moderately low
S01	moderate	moderately high	moderately low
S02	high	approximately even	moderately low
S03	moderate	moderately high	moderately low
S05	moderate	moderately high	moderately low
S06	moderate	moderately high	moderately low
J02	high	moderately high	moderately high
N02	very high	moderately low	moderately high
P06	high	approximately even	moderately high
P10	high	approximately even	moderately high
P13	high	very high	moderately high
P15	high	moderately low	moderately high
S04	high	moderately low	moderately high
P02	very high	very low	very high
P03	very high	approximately even	very high
P05	very high	approximately even	very high
P08	very high	approximately even	very high
P12	very high	approximately even	very high
P16	very high	very low	very high
P17	very high	approximately even	very high
J01	-	-	-
J04	-	-	-
J05	-	-	-
J07	-	-	-
P14	-	-	-
P18	-	-	-

Notes: 1) For some sites (designated in this table with a "-") there was no "more extensive" option (#2) identified and only a "less extensive" option (#1) was evaluated.

4.0 USING THE STUDY RESULTS

The results presented and described in Section 3 of this report, as well as information presented in Section 5 and report appendices, can be used in a variety of ways to inform and guide future forest management actions in the Woonasquatucket River Watershed. In fact, the materials presented in this report, as well as its associated database, have been specifically organized to be easily accessible and transferable for use in future grant proposals and other implementation type applications. The following briefly describes how the study results and other information in this report can be used to facilitate decision making, funding, and project implementation.

4.1 Prioritization and Site Selection

The results of this study provide the WRWC, agencies and other users with a menu of potential riparian forest restoration options. The sites can be queried according to user goals and budgets. In addition to numerical ratings of restoration potential, the report also provides short narratives for each of the sites. The results of the site evaluation ratings in Section 3 are sorted by specific functions and other evaluation criteria to provide users of this report, who might have wide-ranging objectives and cost constraints, with a tool to custom identify the best sites for varying objectives. For example, the user that is interested in identifying the sites with a high potential to provide functional gains in water quality and with low associated costs, can determine the best sites considering these specific sorting criteria.

The inventory presented in Section 3 of this report provides not only a comprehensive listing of suitable riparian restoration sites, but evaluative information about each site. As noted above, this information can be used to identify particular sites that may be appropriate to implement at any given point in time based on available resources and other selection criteria. The various tables presented in Section 3 show how the data can be sorted and organized according to key parameters, or functions, of interest. These tables can be used as quick reference tables, which identify high priority sites based on primary functions. The database itself can also be used for more in depth queries and evaluations. Once a listing of potential site opportunities is developed using the inventory data, the detailed site descriptions presented in Appendix A can be used along with other available information about the site to make an informed decision about what site, or sites, would be best to pursue.

4.2 Preparing Grant Proposals and Evaluating Additional Sites

There are a variety of grant programs, which provide funding for forest management, water quality enhancements, and habitat restoration. The information presented in this report can be accessed and used in developing grant applications to pursue such funding. As described above, the tables presented in Section 3 as well as the database can be used to prioritize and select sites that would be appropriate for a given grant application. The detailed site descriptions presented in Appendix A can also be cut and pasted directly into grant applications along with site photographs and the aerial photos provided in Appendix B. The areas delineated on the aerial photographs are not based on exact property line boundaries, or tax map parcel boundaries. Rather, these delineated areas represent the restoration opportunity that was identified. Delineated areas could potentially cross property line boundaries, in some cases. The materials in Sections 3 and 5 and Appendices A, B, and E should make it easier and more expedient to prepare grant applications. These materials should also increase the likelihood of success by providing very focused information that has already been field verified.

The study results provide grant writers and project sponsors with a list of potential sites to develop healthy-functioning forested riparian buffers so that site work to determine potential sites is not required. However, this study also provides the user with a method for rating and sorting new potential restoration sites. It is hoped that both the site nomination forms (Appendix C) and the site evaluation forms (Appendix D) will be used for identifying and evaluating future potential restoration sites that were not accessible (*e.g.,* privately-owned) or were inadvertently missed during this study.

4.3 Providing Guidance on Project Design

Section 5 of this report provides a comprehensive summary of buffer design considerations tailored to the specific conditions of the Woonasquatucket River

Watershed. This section is a tool for the user, which can be used to plan and design a wide array of projects from wetland restoration projects to upland forest restoration. This section should be used to develop plant lists and to review approaches and techniques for restoration projects in the watershed.

5.0 BUFFER DESIGN CONSIDERATIONS

General Considerations

Possible buffer design approaches include:

1) Restore the buffer to its pre-disturbance condition;
2) Modify the buffer to duplicate a reference condition in the same watershed; and
3) Modify the buffer to achieve specific functional objectives regardless of whether the result resembles the pre-disturbance or reference condition.

The second and third approaches make the most sense from a practical standpoint in developed watersheds, since the primary goal is typically to achieve desired functions related to general goals such as clean water or high quality wildlife habitat. Many parts of the Woonasquatucket River Watershed are significantly changed from the original condition. There have been changes in environmental variables (*e.g.,* hydrologic inputs) related to changes in the surrounding landscape that affect every potential buffer restoration site to one degree or another. For example, the urbanization of the watershed and the extensive damming of the river have changed the flood regime sufficiently that even if the original grade of an historic floodplain forest were restored, it may no longer effectively be able to accommodate the original plant community. If a major goal is to restore the native floodplain plant community, this might require a design elevation different than the original floodplain elevation. Thus, it doesn't always make sense to specifically attempt to restore the original condition when the context has changed. It is valuable to study and to some extent mimic the reference condition in the watershed since, for example, this can help the buffer designer choose a native plant community that will to do well in the conditions specific to the particular watershed. Most of the restoration designs identified in this study end up by containing elements of all three approaches. The second and third approaches are typically more consciously pursued and the first approach, restoration, is achieved incidentally. This is true in a situation, for example, where fill or impervious surfaces are removed from a prior wetland or upland buffer to achieve specific functions and not to specifically restore the prior condition. In pursuing the primary goal of achieving functional objectives, some level of restoration to the pre-disturbance level is also actually achieved. As such the term "restoration" is used very loosely in this report. It refers to the restoration of functions that have been lost or degraded in the watershed generally but does not refer to the literal attainment of the original condition.

Some important technical elements to riparian buffer restoration design are summarized below. It is important to note, however, that recent literature stresses that the best technical designs are often secondary to the importance of partnerships, economics, and social values (LaFayette, Bernard, and Brady, 2000). It is also important to recognize that riparian restoration is a complex undertaking and, although size and complexity can increase functional gains, they also increase the risk of failure (LaFayette, Bernard, and Brady, 2000). It is important to keep projects small and straightforward where funding is limited, and to recognize that monitoring and maintenance is critical to success (LaFayette, Bernard, and Brady, 2000). Lastly, multidisciplinary teams and partnerships between several groups are typically behind the most successful projects (LaFayette, Bernard, and Brady, 2000).

Vegetation

A significant component of the riparian plant community in the Woonasquatucket River Watershed consists of exotic and invasive species. This is especially true in the lower portion of the watershed. The most ubiquitous exotic/invasive species in the watershed is Japanese knotweed (Figure 1-3). This species typically spreads vigorously by rhizomes, forming dense stands and crowding-out native riparian species. It is an escaped ornamental that specializes in invading stream margins and waste places, and is extremely difficult to eradicate once established. Other exotic/invasive species that were commonly noted in the watershed included purple loosestrife (*Lythrum salicaria*), common reed (*Phragmites australis*), Norway maple (*Acer platanoides*), Asiatic bittersweet (*Celastrus orbiculata*), and tree-of-heaven (*Ailanthus altissima*). However, even in the lower portions of the River, in and near Providence, there are relatively undisturbed riparian buffers that lack a dominance of exotic/invasives. Reference sites are relatively undisturbed forested riparian buffers that are dominated by native vegetation and natural soil profiles (Figure 1-4). These sites typically provide riparian buffer functions at target levels, and their characteristics can help with restoration designs. For example, riparian buffer site designs for the Woonasquatucket River should use native plants characteristic of undisturbed portions of the River, since these plants are empirically observed to thrive in the local biological and physical conditions (*e.g.,* climate, soils, competing species of vegetation).

Forested riparian buffer reference sites in the watershed contain a diverse community of native vegetation. Some typical species are listed in Table 5-1. This list is not all inclusive, but is intended to be a useful tool for planning buffer plantings in that it is generally an overlap of native species that were observed at reference sites in the watershed, and species that are generally commercially available. Woody species are emphasized since, for this project, forested buffers are the target condition. Note that this list is intended for riparian buffers rather than specifically for streambank stabilization. Bank bio-stabilization would also utilize species noted in the reference condition, but typically would focus on species such as willow that are available in cuttings and rapidly spread on the immediate river margin from wattles or stakes rather than containerized plantings.

The least costly method of plant restoration is self-recovery, whereby a change in buffer management is implemented and vegetation is allowed to come in on its own. Examples include cessation of mowing, spraying or other forms of woody vegetation suppression, or dam removal that re-exposes the historic riverbank. Self-recovery is generally reserved for situations where there is little money for restoration, soils are stable, and there are no significant problems with exotic/invasive species (*i.e*., exotic species are not prevalent upwind or upstream and are not present in the existing seed bank of the soils on the site). Exotic species are so ubiquitous over much of the Woonasquatucket River Watershed that they would rapidly colonize most sites left to self-recovery, especially in the lower portions of the watershed. This self-recovery approach also only works where buffer designs do not involve intensive design measures such as grading or impervious surface removal and topsoil application, since these measures expose soils to erosion and require immediate re-vegetation through planting, seed, and mulch application.

That said there may be a few situations where self-recovery is a viable option, especially in less disturbed portions of the watershed where the seed bank and seed sources are mostly native. (When the Edwards Dam in Augusta, Maine was removed in 1999, it was decided that self recovery was a viable option for the newly exposed river bank, especially since there were few exotics upstream and there were budget constraints that precluded planting several miles of river bank. The result has been very successful as the banks re-vegetated rapidly with nearly all native species). Most of the prevalent exotic/invasive species in the Woonasquatucket River Watershed are shade intolerant (*e.g.,* Japanese knotweed, purple loosestrife, Phragmites, Russian olive, autumn olive), and will eventually be overtopped and shaded-out as trees gain a foothold. Some caution is advised for the following two specific situations, however. Shade intolerant invasives may be able to survive under the canopy of forest vegetation if the site is at the immediate river edge, especially where there is a southern exposure (*e.g.,* on the north shore of the river). Second, many exotics in the watershed can tolerate some shade, and might remain on the site permanently. An example is Norway maple, which can easily attain canopy dominance in New England. This species even uses ellelopathy (chemical antagonisms) to displace its native neighbors.

Most restoration plans involve the active control of exotic species as well as planting of native species. This can be accomplished through mechanical means such as repeated cutting at ground level or removal of the root systems as well as the above ground parts. Mechanical removal is typically more expensive and labor intensive than chemical control techniques (USDA Forest Service, 1997). Herbicides can be spot-applied, selectively eliminating or stressing exotics and leaving desirable native species unaffected. When guidelines for effective application methods, concentrations, and timing are followed, herbicides can be safe and effective. Where the restoration site is small, there is plenty of volunteer labor, and exotic/invasive species have not reached monoculture or high-density levels, mechanical removal is often the best option. Manual techniques such as hand pulling or cutting with saws and shears can be combined with an educational component whereby the watershed volunteers learn to identify the invasive species. This can result in effective long-term control to the extent they continue their manual eradication efforts over the years and pass on their knowledge to others.

Planting plans should include only native species, preferably those known to grow in the watershed (Table 5-1). Cultivators or biotypes from genetic stocks grown outside the region should be avoided. Plant lists should be as diverse as possible. Using a high number of different species will: add to the ultimate habitat complexity (including vertical structure), avoid wide-scale mortality should a species-specific disease present itself, and enhance educational opportunities on the site.

Tree species should be spaced about 6-10 feet apart. It is good practice to plant seedlings of shade tolerant species between tree plantings. Even gathering and planting acorns between tree plantings can be effective. This will serve as redundancy in case there is mortality of tree plantings and will add to the vertical complexity of forest structure if all live. Shrubs are typically spaced about 3-6 feet apart. Shade intolerant shrubs should not be planted in areas that are intended to become forest, unless on the southern edge.

Mulching around woody plantings is very important to minimize the need to irrigate (mulch prevents rapid evapotranspiration) and to provide slow release of nutrients. Mulch should preferably be well decomposed, dark material. Undecomposed wood chips will actually act as a nutrient sink because of the high carbon:nitrogen ratio and should be avoided since this type of mulch may result in the need to fertilize. Larger plant materials, such as balled and burlapped or large-container stock have greater survival rates and will shorten the total time required to achieve a mature forest condition. Larger materials are more expensive, so if cost savings are important it is preferable to use bare root stock, seedling stock, or small container stock.

Planting plans should consider aspects of plant characteristics that affect buffer functions including: wildlife habitat values, relative nutrient removal rates, abilities to stabilize soils and stream banks, ability to provide shading, and growth rates. Growth preferences should also be considered for optimal placement of plantings. This includes consideration of soil drainage and flooding regimes (*e.g.,* upland, wetland, floodplain), soil texture, aspect or amount of shade, soil compaction, and considerations related to roadside areas such as air quality, and salt. Use of a biologist familiar with plant preferences and plant communities specific to the region will greatly enhance planting survival and vigor.

There are exceptions to the natives-only rule when it comes to retention of existing trees on a restoration site. For example, black locust is not native to Rhode Island, but it is native to the U.S., as close as Pennsylvania, and is not considered a significant problem species with regard to its invasive tendencies. If a mature black locust were present on a buffer restoration site, it may make sense to retain it and plant native shade-tolerant species beneath it. Ideally, the native species will ultimately shade-out the shade intolerant locusts. Where there is some existing vegetation, habitat features such as snags should be retained where possible, as should all natives.

Where stream banks are steep or unstable bioengineering techniques utilizing species that sprout vigorously from cuttings, such as willows and dogwoods, are frequently used. This includes techniques that often involve some combination of plants and "hard" components like stewered wire mesh and riprap, but the primary component is woody vegetation. Specifications for various techniques, such as wattles, vegetative geogrids, brush layering, live cribwalls, and live stakes, are described in the recent stream restoration literature (Palone and Todd, 1997; Fischenich and Allen, 1999). Such live or soft engineering approaches to bank stabilization are recommended over hard engineering techniques such as riprap, flood walls, and gabions (except for live or planted gabions) where conditions allow.

Widths

Optimal riparian buffer width depends on landscape context and objectives (Haberstock et al., 2000). From the standpoint of some wildlife species and species guilds, it is preferable to have minimum buffer widths of several hundred feet in at least some portions of the riparian corridor. Species that benefit from such wide widths include forest interior bird species, cavity nesters such as wood duck, mammals that specialize in riparian habitats such as river otter, mink, and beaver, and herptiles using riparian forests such as wood turtle, northern two-lined salamander, and eastern ribbon snake. Other species, including green frog, small mammals, red-winged blackbird, and disturbance-tolerant mammals such as opossum and raccoon, will persist in riparian forest corridors as narrow as 50 feet or less.

From the perspective of water quality maintenance, the majority of pollutant removal can be accommodated with widths between about 35 feet and 100 feet depending on buffer characteristics, watershed characteristics, and loading rates (Welsch, 1991; Chase et al., 1997; Haberstock et al., 2000). Diminishing returns of removal rates occur beyond 100 feet (or less), but widths as wide as several hundred feet may be necessary to achieve removal rates that approximate natural (background) levels. A commonly cited all-purpose width for effective water quality functions is 100 feet (Chase et al., 1997). Buffer attributes such as steep slopes and soils with low infiltration rates result in less effective water quality maintenance functions, including sediment filtering and nutrient removal (Haberstock et al., 2000). In such cases, wider buffers are required to achieve optimal water quality functions. In urban settings wide buffers are often impractical. Even narrow riparian forested buffers perform important functions, however, and something is always better than nothing. The majority of some important functions such as shading and coarse woody debris and detrital inputs are accomplished with the nearest 30-50 feet of riparian forest. Many buffers also provide the majority of sediment filtering and nutrient removal in the zone from 0 to 50 feet from the river's edge. With riparian buffer restoration projects the objective is simply to make the buffer as wide as practical, using best professional judgement and available scientific literature as guidance.

Many wildlife habitat oriented riparian buffer projects prescribe wider buffers on larger rivers (2^{nd} order and higher) and smaller buffers on 1^{st} order and intermittent streams. However, from a water quality perspective, small streams require buffers that are at least as wide as those for larger streams. Small streams are more susceptible to sedimentation inputs, nutrient inputs, and solar heating, because they are less able to dilute these impacts.

Soils

For many of the potential restoration sites along the Woonasquatucket River, especially in the more urbanized sections, soils are relatively sterile (lacking in organic matter). This often results in situations where detrital inputs have been cut-off due to development (*e.g.,* forest clearing, and addition of impervious surfaces). Some of the potential restoration sites are the sites of former mills that have been removed. The newly exposed soils are typically low in organic content and require soil amendments. A typical amendment is the addition of good topsoil, about 6 inches thick.

Excessively sandy or clayey soils can require special attention to plant lists or soil amendments. For example, pitch pine and red oak are good choices for sandy soils, whereas swamp white oak will tolerate high clay soils. Heavy clays lack optimal aeration, whereas clay loams hold soil moisture well. The depth to bedrock or hard pan are also important considerations, as are pH and parent material.

Hydrology/Flooding Regime/Geomorphology

Many species such as silver maple and black ash are adapted to floodplain habitats, whereas others are intolerant of seasonal flooding. A map of the proposed floodplain showing areas of annual flooding, infrequent flooding, and areas outside the flood zone should be prepared so that the planting plan can reflect the best placement of plants by habitat preference. The limits of flooding can be determined by looking at adjacent or nearby reference sites. Field indicators such as high water debris marks, water stains, alluvial soil deposits, and vegetation communities are usually sufficient to reveal the elevation of the floodplain. Map resources such as USDA soil surveys can also be useful. If possible, observation of actual flooding events is also useful. If grading is proposed, piezometers are potentially useful for identifying wetland elevations within the buffer. However, most projects are fast track and limited by funding. Therefore more rapid techniques such as soil pits, field observations, and informed best professional judgement is crucial. Utilization of species such as red maple, silver maple, black gum, green ash, pin oak, and swamp white oak, which tolerate a wide range of soil moisture conditions is a good hedge.

The stability of the stream bank and channel dynamics/migration can also be very important considerations. The Woonasquatucket River is relatively stable and the channel is relatively confined (channel migration across the floodplain is not typical). In most places on the River, if stream bank work is necessary (for example, if a flood wall is to be removed) bank stability at natural levels can be achieved by feathering back the bank to a stable angle of repose and establishing vegetation. A fluvial geomorphologist or stream restoration specialist should be on the project team if the stream bank is proposed to be altered.

It is important to note that attempts to achieve a floodplain condition through grading increase the likelihood of planting failures. For example, many natural floodplains have a "park-like" appearance where even-aged cohorts of mature floodplain trees dominate and the understory is sparse or absent. This is because the mature trees are able to tolerate spring high floods and ice damage but shrubs and saplings are not. The mature trees established during successive dry years. As such it can be less risky to try to achieve the high floodplain (deep flooding and ice action only occasionally) rather than the low floodplain (deep flooding and ice action most years). The project sponsor(s) simply need to realize that floodplain plantings may fail and replanting could be necessary if extensive high floods occur during the growing season or extensive ice damage occurs during the winter. It is also important to note that streambank and floodplain projects have a high risk of erosion potential. Several functions including flood storage are maximized to the extent that a floodplain condition can be achieved.

Depth to the water table affects many aspects of riparian buffer design, including:

- *Species composition***.** Although several species can tolerate a wide range of soil moisture regimes, as discussed above, most species are relatively specific to a particular drainage class. It is important, therefore, to place specific species at the elevation which will correspond to the soil moisture regime they are best adapted to. Publications such as the U.S. Fish and Wildlife Service National List of Plant Species that Occur in Wetlands (1988) are useful for this type of planning.
- *Vegetation height***.** In the northeast, in soils where the depth to the water table is 2 inches, the maximum height of vegetation is about 3 feet; a water table at 4 inches corresponds to a maximum height of 6 feet; 6 inches to 45 feet; 12 inches to 60 feet; and 17 inches to 75 feet (Verry, 2000).
- *Support of heavy equipment***.** To support heavy equipment for grading and other tasks, the depth to the water table should be at least 18 inches (Verry, 2000).
- *Water quality***.** Water quality functions can vary with water table depth. For example, denitrification occurs more efficiently in systems where there is a shallow fluctuating water table, such as with poorly drained soils or somewhat poorly drained soils. Inundated (very poorly drained) or well drained systems do not convert nitrogen to a gaseous form as readily.

Topography

Where grading is used to enhance the functions and values of a restoration site there are several rules of thumb. The land surface should be designed in a way that is hydrologically beneficial. Topographic lows or swales should be interspersed with mounds or high points to encourage infiltration and discourage concentrated surface runoff. This will enhance water quality functions such as sediment settling and pollutant assimilation or conversion. In addition, topographic heterogeneity enhances habitat complexity and plant and animal species diversity. Where intermittent or small perennial streams are channelized as they flow through the buffer site, creation of more tortuous flow paths can also enhance wildlife habitat and water quality functions. Fluvial geomorphology principals should be considered when designing stream sinuosity, however, since too much sinuosity can cause a stream bank to alter its course causing erosion and sedimentation as it finds its flow path. A detailed grading plan is not essential for work landward of the streambank if the contractor is closely supervised by a knowledgeable biologist, engineer, landscape architect, or planner. But for work in-stream or on the bank it cannot be dispensed with. Contractors typically take pride in making sites as flat as possible and making a site of hills and swales may be counterintuitive to them, but once convinced of the objectives, they can get creative about site design. On-site supervision and creativity may be important since site conditions such as unexpected bedrock may necessitate field adjustments to the grading plan.

Examples

The following potential riparian buffer project sites are used as examples to illustrate specific design components that can be used to correct for existing deficiencies. The sites are also used to demonstrate specific restoration considerations in the watershed.

The ***Smith Appleby*** site has several deficiencies with regard to optimal function. Possible design components to address corresponding deficiencies are summarized in Table 5-2.

There are no ROW issues, reasons to suspect soil contamination, geologic

Figure 5-1. Smith Appleby (S05).

constraints (*e.g.,* steep slopes, ledge near surface), or other obvious practical considerations that would preclude a restoration project at the site. A critical step, however, is to determine if the landowner is amenable to a restoration project. There is a wide range of potential project complexities/levels of effort. The most basic is to stop mowing and let the site revert to forest on its own. The most complex is to re-grade the site, restore the stream channel, eradicate the exotics and plant a well-planned native community to maximize habitat and water quality functions. Obviously, the greater the level of effort, the more the functional gain there is and the higher the costs are. Therefore, decisions need to be based on a multitude of factors from project budget, to objectives and estimated benefit/cost ratios.

As with many of the potential restoration sites in Providence, the ***Olneyville Post Office*** parking lot site had a floodwall at the river margin and was dominated by impervious surfaces. Typically, restoration sites dominated by impervious surfaces and floodwalls will have the greatest restoration costs of all projects, but also have very high functional gains. Due to extremely high costs, projects involving impervious surface removal often require partnerships. When impervious surfaces are removed from historical industrial areas, it is necessary to consider the possibility of soil contamination. Even if soils beneath impervious surfaces are not contaminated they will likely be devoid of organic matter (*i.e.,* the soils have become sterile) and will require significant soil amendments, such as topsoil addition.

Figure 5-2. Olneyville Post Office Parking Lot (P09).

The ***Manton Stop-N-Shop Grocery Store*** site contains recently disturbed soils with small Japanese knotweed sprouting vegetatively (*i.e.*, not from seed). Left unmanaged a pure monoculture of mature knotweed will form and will persist indefinitely. This will have a negative effect on native plant diversity and on wildlife habitat. As such, mechanical or chemical removal is recommended if possible. However, if the primary objective is water quality maintenance, exotic/invasive plants are often as good or better at stabilizing soils and assimilating nutrients. Eradication can be very labor intensive and/or expensive. Some references advise that basin-wide restoration should pick their battles because the war against exotics may not ever be won. Most sites that involve large-scale eradication of exotics will require frequent monitoring and maintenance.

Figure 5-3. Behind Stop-N-Shop Grocery Store in Manton (P18).

Since there are several dams along the main stem of the Woonasquatucket River, it is a good idea to consider how they fit into the overall restoration effort. If a riparian buffer restoration were implemented along the margin of an impoundment and several years later the dam were removed, narrowing the river and stranding the restoration site, several problems could result. For example, bank stabilization work would no longer be relevant, and plants may no longer be in the correct context (*e.g.,* floodplain plants may no longer be in the floodplain). Realistically, many and maybe most dams will not be removed.

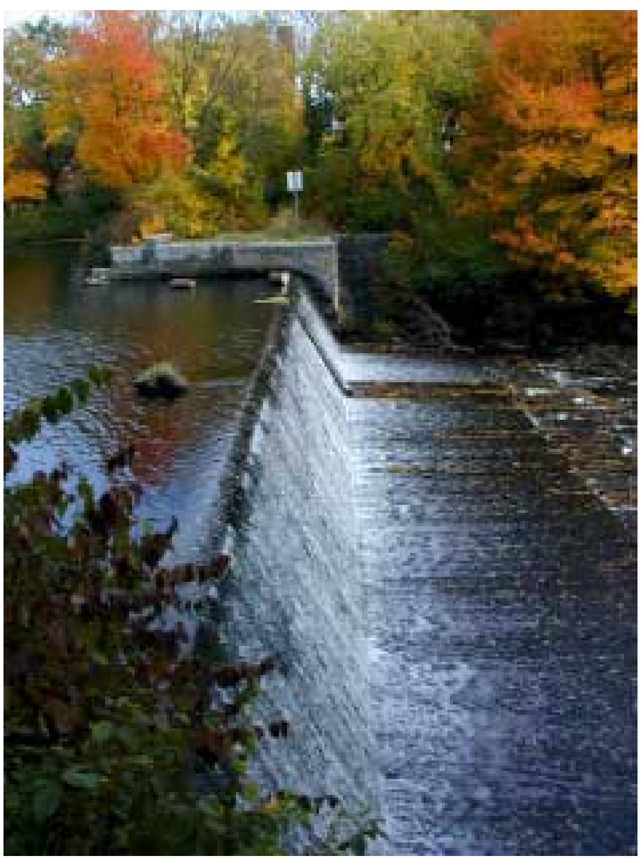


Figure 5-4. Lymansville Dam.

For example, the dam for Georgiaville Pond would be difficult to remove given the existing location of lakeside homes and parks. However, it would be useful to have a list of dams that could be removed with great ecological gain and little socioeconomic cost.

Table 5-1. Typical native species found in forested riparian reference sites in the Woonasquatucket River watershed.

Uplands	Wetlands/Floodplains
Trees	**Trees**
Red oak *(Quercus rubra)*	Silver maple (*Acer saccharinum*)
White oak *(Quercus alba)*	Red maple (*Acer rubrum*) (1)
Black oak *(Quercus velutina)* (4)	Green ash (*Fraxinus pennsylvanica*)
Sugar maple (*Acer saccharum*)	Swamp white oak *(Quercus bicolor)*
White ash (*Fraxinus americana*)	Pin oak *(Quercus palustris)*
Black cherry (*Prunus serotina*)	Black willow (*Salix nigra*)
White pine (*Pinus strobus*) (1)	American elm (*Ulmus americana*) (2)
Beech (*Fagus grandifolia*) (4)	Box elder (*Acer negundo)*
Hop-hornbeam (*Ostrya virginiana*)	Black ash (*Fraxinus nigra*)
Basswood (*Tilia americana*)	Cottonwood (*Populus deltoides)* (1)
White birch (*Betula papyrifera*)	Yellow birch (*Betula alleghaniensis*) (1)
American hornbeam (*Carpinus caroliniana*) (1)	Hemlock (*Tsuga canadensis*) (1) (2)
Eastern red cedar (*Juniperus virginiana*)	Black walnut (*Juglans nigra*) (1) (3)
Flowering dogwood (*Cornus florida*)	Black gum (*Nyssa sylvatica*) (3)
Black birch (*Betula lenta*)	Larch (*Larix laricina*) (1)
Bitternut hickory (*Carya cordiformis)* (4)	Sycamore (*Platanus occidentalis)* (1) (4)
Shrubs	**Shrubs**
Bayberry (*Myrica pennsylvanica*) (1)	Sweet pepperbush (*clethra alnifolia*)
Witch hazel (*Hammamelis virginiana*)	Highbush blueberry (*Vaccinium corymbosum*)
Black huckleberry (*Gaylussacia baccata*)	Swamp azalea (*Rhododendron viscosum*)
Black chokeberry (*Aronia arbutifolia*) (1)	Common elderberry (*Sambucus canadensis*)
Hazelnut (*Corylus americana*)	Buttonbush (*Cephalanthus occidentalis*)
Staghorn sumac (*Rhus typhina*)	Winterberry (*Ilex verticillata*)
Serviceberry (*Amelanchier canadensis*) (1)	Wild raisin (*Viburnum cassinoides)*
Mountain laurel (*Kalmia latifolia*) (4)	Northern arrowwood (*Viburnum dentatum*)
Maple-leaf viburnum (*Viburnum acerifolium*)	Spicebush (*Lindera benzoin*)
Sweet fern (*Comptonia peregrina*)	Pussy willow (*Salix discolor*)
Beach plum (*Prunus maritima*) (3)	Swamp rose (*Rosa palustris*)
Herbs	**Herbs**
Hay-scented fern (*Dennstaedtia punctiloba*)	Tussock sedge (*Carex stricta*)
Deertongue grass (*Panicum clandestinum*) (1)	Soft rush (*Juncus effusus*)
Christmas fern (*Polystichum acrostichoides*)	Blue flag iris (*Iris versicolor*)
Switchgrass (*Panicum vergatum*)	Sensitive fern (*Onoclea sensibilis*)
New England aster (*Aster Nova-angalia*) (1)	Ostrich fern (*Matteuccia struthiopteris*)
Canada goldenrod (*Solidago canadensis*)	Cinnamon fern (*Osmunda cinnamomea*)

(1) Species is commonly found growing naturally in both uplands and wetlands (especially drier wetlands).

(2) Species is not recommended for planting due to susceptibility to disease.

(3) Species was not actually observed in the reference condition locally, but is usually commercially available, offers exceptionally high wildlife food value or other functional benefits, and is native to riparian buffer areas in Providence County.

(4) Species is not commonly available from nurseries, but is common native species in Providence County and does offer high value for one or more functions and should be considered if available.

Table 5-2. Smith Appleby Site - Deficiencies and Corrective Design Components.

Deficiency	Corrective Design Component
Site grades smoothly and consistently to the stream	Add topographic complexity. Grade site so that a portion of the land slopes away from the stream. Incorporate swales that will promote infiltration. Design topography to discourage concentrated surface flows perpendicular to contours.
Stream is channelized	Modify channel to make more natural. Install natural stream-bed substrate (*e.g.,* appropriately sized boulders, rocks, cobbles, pebbles, sand). Incorporate sinuosity. Use a fluvial geomorphologist to determine appropriate sinuosity and bed materials according to contributing drainage area and flow regimes.
Mowed lawn to stream edge.	Discontinue mowing. Plant a diverse community of native woody vegetation.
Exotic/invasive (*e.g.,* Norway maple) is dominant tree on and near site.	Control exotics and promote natives if wildlife habitat and plant diversity are a priority. Retain existing mature trees but plant natives in understory if primary objective is water quality. The hope is to shade-out seedling establishment of the Norway maple so that when the canopy trees finally die-off the site will be mostly natives.

6.0 PROJECT DEMONSTRATION SITE

One of the primary objectives of this project was to identify and construct a riparian restoration demonstration site within the Woonasquatucket River Watershed, including an appropriate public education component. Kleinschmidt worked closely with the WRWC, the DEM, and others to discuss site selection options for a demonstration project. Based on an analysis of the inventory data and discussions regarding partnering opportunities and other practical considerations, the Riverside Mills site (Site # P10) was selected as the demonstration project site. The following describes how the demonstration site was selected, provides information on site construction and how monies from this study will be used to aid in the restoration of the Riverside Mills site, and describes the proposed education component of the design.

6.1 Site Selection Process

A three-step process was used to select an appropriate demonstration project for this study:

1) Identify appropriate selection criteria.
2) Apply the selection criteria the inventory data to prioritize and identify potential candidate sites; and
3) Recommend a preferred demonstration site.

Selection criteria used included the following:

1) Low Cost
2) High Practicability (including partnering potential)
3) High Water Quality Benefit
4) High Education and Aesthetics (including visibility)

Because of the limited available funding, cost was a key consideration in the site selection. Only low cost restoration options (<$15,000) were considered for the demonstration site. Practicability was a key consideration because of the desire to implement the project in 2001 or 2002. Only those sites located on existing public lands were considered to ensue the project could be implemented in an expeditious manner.

Partnering potential was also an important practical consideration to maximize the potential of the project. The water quality benefits associated with site restoration were important because water quality enhancement was one of the key goals of the project. Lastly, education and aesthetics were important to ensure a viable public education component could be incorporated into the project.

Based on the selection criteria noted above, five potential demonstration sites were identified, one in each of the municipalities within the watershed. These five sites were:

1) Cutler Brook (#G01)
2) Smith Appleby (#S05)
3) Johnstown Ballfield (#J03)
4) Allendale Mill (#N01)
5) Riverside Mills (#P10)

Based on additional discussions with the Woonasquatucket River Watershed Council, DEM, and other knowledgeable parties, the Riverside Mills site was identified as the most promising demonstration site. Of all the sites evaluated, Riverside Mills offered the greatest current opportunities, particularly in terms of practical considerations such as public ownership and leveraging potential. It was recognized that the Contractor could combine its expertise and contract dollars with the current remediation and bike path planning and construction activities being carried out by the US ACOE, US EPA, and the City of Providence to develop a significant restoration site, both in terms of size and visibility. Figure 6-1 includes photographs of the Riverside Mills site illustrating the conditions of the site prior to restoration.

Specific rationale for selecting the Riverside Mills site included the following:

- The site is specifically mentioned in the U.S. Forest Service grant proposal and the Forest Service has expressed interest in the site.
- The site is publicly owned.
- The site is located on the mainstem of the river, which is the focus of this study.

Figure 6-1. Riverside Mills Project Demonstration Site – Representative Photos of Existing Conditions.

An early successional vegetation community typical of disturbed soils has established on the old mill site (upper left). A variety of exotic invasives including common reed (left center of photo) have become established (upper right). The cut and fill soils (Udorthents) on the site are relatively sterile and lack organic matter. Also, there is a fair amount of debris such as brick and concrete slabs on the site (lower left). There are no floodwalls or eroding banks at the immediate river margin, however, exotic species such as purple loosestrife (center of photo) are interspersed with native species like sweet pepperbush (left side of photo) at the river edge (lower right).

- The site is relatively large offering opportunities for a more comprehensive restoration strategy.
- There are considerable opportunities to partner with the City of Providence, the EPA, and the Corps of Engineers and to leverage other committed funds. This will allow the existing grant funds to go further.
- Plans for the greenway and bike path will significantly increase the visibility of the site and offer excellent opportunities for education and interpretation at the site, which could be done in connection with the bike path.
- The timing is good to take advantage of planned activities in 2001 at the site, including planned grading.
- The site is adjacent to some relatively high quality existing wildlife habitat and offers an opportunity to expand this existing habitat making for a large contiguous forested area.
- The site is near several other identified restoration opportunities, which could ultimately be combined to create a continuous section of high quality buffer.
- There is no development, or development pressure (due to the highway), on the other side of the river. This adds to the overall value of the restoration opportunity.
- There are opportunities to prevent continued establishment of exotic species by acting as soon as possible.
- There is not a lot of impervious surface directly adjacent to the river. This allows for the restoration of a contiguous buffer with high ecological integrity. And, there is substantial impervious surface in the immediate contributing watershed, which means that there are sources of elevated nutrients, pollutants, and sediments. As such a well-designed buffer is a more important last line of defense for water quality maintenance in the river (as opposed to buffer projects in undeveloped portions of the watershed where there is less potential for substantially improving water quality).
- This site is good with respect to environmental justice.
- There are no topographic or geologic constraints to site restoration such as steep slope, or shallow-to-bedrock soils.

Many of the reasons noted above represent practical considerations. In fact the Riverside Mills site scored a 1.000 (on a scale from 0.000 to 1.000) for practical considerations. It was important to give these factors (Section 3) a relatively heavy weight given the desire to construct a demonstration project as soon as possible. The decision making team also believed that, given the leveraging potential at Riverside Mills, the benefit/cost ration for this site would be very good. In the end, experience suggested that practical and logistical factors are often the most important when it comes time for implementation. In addition to the practical considerations, Riverside Mills also offered excellent potential for ecological restoration, including potential gains in water quality and wildlife habitat functions. The site scored well on all ecological factors, with an overall ecological rating of .700 (on a scale from 0.000 to 1.000).

6.2 Project Implementation

At the time of publication, the implementation phase was currently underway. Kleinschmidt has completed detailed grading and planting plans, along with associated habitat restoration and planting specifications for two restoration areas on the Riverside Mills site. These design plans were finalized and submitted to the WRWC, the RI DEM, the City of Providence, and the US ACOE. The plans are not attached to this report, but this section will highlight some features of it and some lessons learned. In addition to supporting the design work, funds from the riparian buffer restoration project were used to acquire native plant materials, contract with a local landscaping firm (to help with installation and maintenance), and develop educational materials for the site (Section 6.3). Plant material and educational signs (or other educational material) are scheduled to be installed during 2002. This allowed plant materials to be contracted one year in advance and grown specifically for this project, which is often a recommended procedure for restoration activities.

The design work was closely coordinated with the Project Manager at the ACOE who was charged with developing the site clean-up and redevelopment design plans. The advantages of partnering with a larger project included the fact that many aspects of the design could be carried-out as part of the overall site clean-up and redevelopment.

Kleinschmidt only provided designs for the desired grading, and specs for required soil types and depths, and other design parameters (*e.g.*, habitat log placement and microtopographic features), and these plans will be carried-out with other funds, leaving the site in a plantable condition. It will be Kleinschmidt's responsibility to oversee installation of the native plant material once the site has been brought to final grade. Labor for plant installation will be provided by volunteers from the WRWC and other state, federal and NGOs, in addition to the paid labor from the local landscaping firm. The volunteer labor pool will also include two volunteers from Kleinschmidt that will help provide assistance with installation methods/guidelines. Long-term details such as maintenance/monitoring will be resolved through coordination with the the City of Providence, the WRWC, and the DEM. For example, some level of exotic species management or site maintenance such as watering or plant material replacement could be necessary, although the site design was intended to minimize the need for such efforts.

The plant list for the riparian buffer restoration areas includes only native plants that were observed in intact riparian buffers, or reference sites, in the watershed. Wildlife food/cover values were also considered when assembling the plant list. More than 40 species of native trees, shrubs, and herbs were used to maximize plant diversity and hedge against large-scale mortality from disease or other environmental variables. Several types of native wildflower mixes were also specified. Native riparian tree species such as silver maple, red maple, and swamp white oak, that can grow well in a variety of soil moisture regimes were used extensively at a variety of elevations on the site. Other species were more carefully located at specific elevations due to more narrow site requirements. For example, sweet fern needed to be placed in the most exposed, higher elevations, and tussock sedge was restricted to the topographic low points.

One of the restoration areas within the Riverside Mills site was designed to capture stormwater from the contributing area and promote infiltration, polishing any pollutants in the stormwater runoff and protecting water quality in the Woonasquatucket River, and ultimately the Narragansett Bay. The design elevation of the lower portions of this particular restoration area were designed to result in the creation of forested wetlands that would be seasonally inundated and saturated through most of the growing season, resulting in optimal conditions for denitrification. Site work during 2000 and 2001 was used to estimate potential floodplain elevations or flood stage elevations. The elevations of existing wetlands immediately upstream and indirect indicators such as drift lines (or debris racks) and alluvial soils were used to gain empirical evidence of potential flood elevations for design purposes.

The restoration design calls for several habitat logs to be placed within the restoration areas. These are to be salvaged from site clearing and grading operations and are intended to enhance microtpographic heterogeneity, and provide microhabitat for plants (*e.g.,* nurse logs) and small animals, once they begin to decompose. The design also calls for microtopographic complexity. Instead of completely smooth grades, the design calls for a series of pits and mounds. Forested cover types were favored for several reasons, including the objectives of the funding agency (the USFS), and the desire to achieve certain functions associated with forested riparian systems (Sections 5 and 6.3). In addition, this site has an existing problem with exotic/invasive species such as purple loosestrife, Phragmites, and Japanese knotweed – all relatively shade intolerant species. To the extent that we can achieve shaded/forested conditions, the long term control of these species will be somewhat simplified. Note, however, that there will be large areas of open space with mowed grass or recreation features on the Riverside Mills site, and the edge of forested areas will likely be the subject of a continuing monitoring and control effort with respect to exotic/invasives.

The forested riparian buffer design calls for intensive forest plantings in two areas, as well as continuous plantings in a narrow belt along the immediate shoreline. The biggest challenge presented by partnering with a large project was coordinating with multiple objectives and multiple agencies to accomplish the objective (to create functioning forested riparian buffers). Other site objectives and considerations ran the gamut from safety and sight lines, recreation features, functionality, maintenance, contaminated soil clean-up, greenspace corridors, stormwater management, and aesthetics. This resulted in several design revisions to accommodate overriding considerations. For example, initial ideas of good places to implement the forested riparian buffers had to be changed due to the need to accommodate recreation features, paths, and safety considerations (*e.g.*, blocking views to some portions of the site). One design needed to be changed to accommodate an existing concrete slab that was to remain and be covered with clean topsoil for practical reasons, preventing excavating down to the design elevation. The final design for one of the restoration areas, within the Riverside Mills site, needed to accommodate an adjacent retaining wall, an adjacent bike path, and stormwater inputs, all of which were dictated by other aspects of the overall site design.

Overall, such coordination considerations are minor, and it was clearly advantageous to partner with this large project. Kleinschmidt feels that this Riparian Buffer Restoration Project will result in enhanced ecological values of the site. Also, the Project team was able to leverage the funding (*i.e.,* there is no way the soils testing, grading, site clean-up of contaminated soils, and other contracting expenses could have been afforded without this partnering). The American Heritage River designation and the federal (EPA, USFS and others) and local efforts to restore this river are clearly resulting in synergies. Overall, where possible, other forested riparian buffer restoration sites in the watershed should take advantage of potential partnering with larger projects as well.

6.3 Education Component

The following briefly outlines a concept plan for an education component to the riparian restoration site demonstration project planned for the Riverside Mills site in Providence.

Concept Plan

The education component of the demonstration project will consist of an interpretive walking trail designed in concert with the restoration site. The trail will include an interpretive sign, or kiosk, that will describe the functions and values of forested riparian buffers as well as the history of the site and principles and objectives of restoration ecology. The sign will also highlight the demonstration site as an example of activities within the watershed to enhance water quality and other resource values. The demonstration site and walking trail will be sited to work in conjunction with the Woonasquatucket bikeway that will traverse the site. The walking trail will be designed so that additional trails and/or interpretive information can be added to expand the educational and recreational value of the project.

The interpretive walking trail could have numbered sign posts keyed to a print brochure. Each signpost, or “station”, along the trail would highlight a particular function/value of riparian buffers and/or some aspect of the restoration at the site. The trailhead would be sited along the bike path and could be designed to work in conjunction with the proposed boardwalk through the wetland restoration site, which is immediately adjacent to one, of two, riparian restoration areas. An interpretive sign could be designed and located at the trailhead providing general information about the value of riparian areas, the site history, information on restoration, and serve as a distribution point for the print material. Alternatively, the trailhead “sign”, or kiosk, could be designed to contain all of the theme information (see below) keyed to a site map to show locations referred to. All sign and print material could be designed to be bilingual.

Themes

The following is a list of potential themes that could be highlighted within the demonstration site, either with numbered posts keyed to an interpretive brochure, or through a large display, or kiosk, keyed to a site map. These would include general information about the value of riparian buffers and the restoration project, which would be contained on an interpretive sign or as part of an introduction on the brochure.

1) Buffers and Stormwater Management
2) How Buffers Improve Water Quality
3) Buffers as Wildlife Habitat
4) How Buffers Affect Hydrology
5) Wetlands and Forests as Buffers
6) Wetland Restoration
7) Natural Wetland Habitat
8) Riparian Buffer Restoration

Individual Station Descriptions for Brochure

Text for each of the proposed stations is presented below. This material is provided as a starting place for development of a brochure, or kiosk, highlighting the value of riparian areas and ongoing restoration efforts. It is assumed that the text provided below will be edited, as necessary, to accommodate the final brochure format and design.

General Introduction: Restoring Forested Riparian Buffers on the Woonasquatucket River

Location: The following text would be incorporated as introductory material on the interpretive brochure and/or on an interpretive sign, or kiosk, located at the beginning of the interpretive trail.

Brochure/Sign Text: Areas of forest vegetation adjacent to rivers and other waterways provide important ecological and socioeconomic functions. These forested riparian areas help to protect and enhance water quality by serving as buffers that filter pollutants before they reach the waterway. They also provide important fish and wildlife habitat, as well as aesthetic, recreation, and educational values. Efforts are underway throughout the Woonasquatucket River corridor to restore natural wetland and forested riparian areas and improve water quality and other functions and values. The Riverside Mills Riparian Restoration Site serves as a working demonstration of riparian buffer restoration and how such restoration can benefit the surrounding community. Agencies and organizations contributing to this project include the Rhode Island Department of Environmental Management (DEM), the Woonasquatucket River Watershed Council, the US Forest Service (USFS), the U.S. Army Corps of Engineers (ACOE), the US Environmental Protection Agency (EPA), the National Fish and Wildlife Foundation, the City of Providence, and The Providence Plan.

This site was once an active woolen mill. Founded in 1863, this mill went on to become a major manufacturer of woolen fabric. Riverside Mills was the first textile mill in the US to install electric arc lighting in 1879. This strong, brilliant light was a great and economical improvement over the gas lighting that preceded it. Riverside Mills was absorbed into the American Woolen Company (along with most of the woolen/worsted mills on the Woonasquatucket) in 1899. A 2-story brick flat-roofed office (*ca* 1900) was the only building to survive a 1988 fire that destroyed the rest of the Riverside Mill complex. In the twentieth century the mill complex fell into disuse as the manufacturing sector declined in New England. A fire in October 2001 almost destroyed this last remaining building but the building was salvaged. The industrial legacy of this site resulted in soil contamination that was cleaned-up by the ACOE and the EPA in 2001. During this clean-up effort, many tons of soil and debris were removed and the site was then topped-off with clean topsoil and graded. Aside from the clean up of soil contamination other objectives of the project included restoration of wetlands and riparian buffers along the Woonasquatucket River, and the development of interpretive walking trails.

Station #1: Buffers and Stormwater Management

Location: Station at an outfall (culvert opening) that drains into Restoration Area A or other culvert that directs stormwater runoff through the site.

Brochure Text: Urban runoff can contain a variety of harmful pollutants that can degrade the water quality of the rivers, streams, ponds, and wetlands. Such pollutants include sediments (*e.g.*, sand and silt), nutrients (*e.g.*, nitrogen and phosphorous), hydrocarbons (*e.g.,* in oil from leaking crankcases), toxic heavy metals (*e.g.,* lead and cadmium), trash and debris, increased temperature, pathogens (*e.g.,* bacteria or viruses from animal/human waste), pesticides, and oxygen-demanding substances (*e.g.,* discarded food wastes, animal/human waste, and decaying plant matter such as lawn clippings). Negative impacts to plants, fish and wildlife can result when urban runoff is permitted to drain directly into rivers and streams by means of overland flows, shallow subsurface flows, or as concentrated drainage from storm drains and culvert pipes. Riparian forests can serve to buffer rivers and streams from urban runoff by filtering pollutants before they reach the water. Restoration Area A (see diagram)[1] was designed as a forested riparian buffer to accommodate runoff from the surrounding area. The area was designed in a basin configuration to allow sediments to settle-out, and to encourage stormwater to infiltrate into the soil-root zone where pollutants are taken-up by plants, converted to

[1] This diagram does not currently exist but will be produced once the final site restoration work has been completed.

harmless materials, or permanently incorporated into the soils. For more information on how this area cleans stormwater runoff before it enters the adjacent wetland area (see diagram)[1] and the Woonasquatucket River, see Station #2. Can you see evidence of stormwater runoff entering the area? How about evidence that the area is trapping sediments or other pollutants?

Station #2: How Buffers Improve Water Quality

Location: Where there is a view of the lowest elevation in Restoration Area A where stormwater could be ponded and sediment/debris might be seen.

Brochure Text: Vegetated riparian buffers filter sediments and pollutants from runoff by promoting infiltration and storage, as well as discouraging concentrated runoff. Since phosphorous and many other pollutants are bound to soil particles, sediment settling and trapping is a critical buffer function. Biogeochemical processes associated with naturally vegetated buffers promote the retention or conversion of nutrients/pollutants that are in solution. For example, buffers (especially those with saturated, but not inundated soils) promote the process of denitrification whereby biologically available nitrogen is converted to a gaseous form and removed from the system. Another nutrient/pollutant removal mechanism is plant uptake. However, this only results in a net removal to the extent that the system is accumulating biomass, or there is a flux of biomass from the system (such as plant harvesting, or more detritus leaving the site than entering). Forested buffers also maintain stream water quality by keeping water temperatures cool in the summer through shading. Lastly, buffers promote stream bank stabilization, thereby protecting downstream water quality. Unfortunately, in heavily urbanized watersheds only about 10% of stormwater runoff passes through a vegetated buffer.

Station #3: Buffers as Wildlife Habitat

Location: Where habitat logs are visible.

[1] This diagram does not currently exist but will be produced once the final site restoration work has been completed.

Brochure Text: Note the logs on the ground in Restoration Area A. These logs were salvaged during construction, of a portion of this park, and placed in the area to provide microhabitat for plants and wildlife. As they begin to decompose, plants will sometimes germinate and grow on the logs (often called nurse logs). Species of small mammals, insects, and possibly amphibians will use the logs to hide in, or under. Plant and wildlife diversity and productivity are often greater in riparian forests than in non-riparian forested systems. A disproportionately high number of wildlife species utilize riparian forests as a preferred habitat. Riparian systems offer a source of perennial drinking water for mammals and birds. The interface of river and forest forms productive edge habitat. Riparian forests can serve as important travel and dispersal corridors for wildlife when they are relatively contiguous, especially in urban or suburban areas where there is a lack of other habitat or there is a high degree of fragmentation. Increased light levels, varying topography, varying moisture regimes, and irregular edges between aquatic and terrestrial cover types often enhance the vertical and horizontal complexity of vegetation at the river margin. The structure that develops in a mature riparian forest, including snags, rotten logs, and thick duff layers, is also an important habitat feature that open habitat types like lawns do not provide. Where open water and forest are next to each other, species such as wood duck that nest in tree cavities near open water, and mammals such as raccoon and mink that forage along the water's edge, find valuable habitat.

<u>Station #4: How Buffers Affect Hydrology</u>

Location: Not site specific. Site in accordance with other stations.

Brochure Text: In addition to impacting water quality, urban watersheds alter the quantity and timing of stormwater runoff and river flows. Runoff volume from impervious surfaces such as roofs, paved roads, and parking areas is much greater than it is in forests and fields because the water is not able to infiltrate into the ground. Naturally vegetated buffers and watershed parcels act like sponges, storing water during rain storms and floods and releasing it slowly during dry periods. As such, buffers and naturally vegetated areas in watersheds decrease property damage and streambank erosion during floods, and help to maintain river base flows for fish and wildlife during dry months in the summer. Forest trees are particularly good at reducing erosion from concentrated runoff or direct impact of raindrops. Forests intercept water in their canopies, form thick forest floors of leaves and twigs that protect mineral soils from erosion, and lessen peak runoff volumes by allowing infiltration into the soils and uptake of water through the leaves. This riparian forest restoration area was created in 2002. It will probably take several years for a good, thick forest floor of leaves, needles, and twigs to develop. Can you see a forest floor developing in this area?

<u>Station #5: Wetlands and Forests as Buffers</u>

Location: Where both forested and wetland areas can be seen.

Brochure Text: Riparian buffers can be wetlands or uplands and can be forested or non-forested. The type of buffer affects the degree to which it can perform various functions. From this station, both non-forested and forested wetlands and uplands are visible. Wetlands are often more effective than uplands at trapping and storing sediments because they are often in topographic lows with basin configurations. They are also better at buffering rivers from certain pollutants such as nitrogen. However, wetlands themselves should be buffered if possible to maximize their own ability to perform functions such as wildlife habitat and water quality maintenance. Riparian forests immediately adjacent to waterbodies, whether upland or wetland, serve to shade the water and prevent excessive temperatures. Such forests also provide organic matter and large woody debris to the stream channel that is important for fish and insect habitat. Although fields cannot perform these specific functions as well as forests, they are very good at other functions such as filtering sediment, because of the dense, low vegetation.

<u>Station #6: Wetland Restoration</u>

Location: Near wetland restoration site.

Brochure Text: The wetland visible from this station, including the area with ponded water and aquatic vegetation and the area dominated by shrubs surrounding it, is a wetland restoration project that was completed in 2002. This area was previously a wetland that was dominated by a near pure stand of purple loosestrife. Purple loosestrife is an exotic (non-native), invasive plant that displaces native species. This plant and other exotic invasive species like Japanese knotweed do not offer high quality wildlife habitat and reduce overall plant and wildlife diversity (biodiversity). They are common in the lower portion of the Woonasquatucket River watershed. The previous wetland soil and the purple loosestrife seeds in it (called seedbank) were removed and replaced with clean topsoil. The interior portion was excavated down to a lower elevation to achieve perennial standing water. This ponded area dominated by aquatic plants was designed to be too deep for optimal purple loosestrife growth, and was also intended to enhance plant and wildlife habitat diversity by adding a different habitat type than previously existed on this site. Biodiversity and overall habitat quality on a site depend on a variety of factors including habitat diversity (including the range of different soil types and elevations) and the presence of exotic/invasive plants. All portions of this wetland restoration area were planted with native vegetation known to grow naturally in northern Rhode Island. However, because there are purple loosestrife (and other exotic plant) seed sources in the surrounding area, it will be an ongoing effort to keep them from becoming dominant at this site. Although exotic plants are a problem from the perspective of plant and wildlife habitat, they typically perform water quality functions as well as native species.

Station #7: Natural Wetland Habitat

Location: Along the boardwalk where native trees and low/ponded habitat is visible.

Brochure Text: This station overlooks a natural wetland that was not disturbed during the overall restoration except for construction of the boardwalk. The trees and shrubs in this wetland are mostly willows. Exotic invasives like purple loosestrife and Japanese knotweed are relatively shade intolerant and cannot vigorously expand beneath the shade of the willows and other native trees. They can be found in this wooded wetland but do not crowd-out the native species to the same degree they do in open-canopy habitats. Many different species of native ferns and herbs (non-woody vegetation) grow beneath the willow canopy as a result of the lack of competition from exotics. Note also the different moisture regimes in this wetland. Seasonally ponded areas or swales occur in the lowest areas. During floods the entire wetland is flooded by overbank flows from the Woonasquatucket River. This makes this wetland a forested floodplain. Forested floodplains play an important role in slowing flood velocities and increasing sediment deposition. Can you see evidence of past flooding (such as water stains on tree trunks, or debris piled up against something or deposited in a line by water)? Can you find places where purple loosestrife is growing because of a break in the willow-dominated canopy?

Station #8: Riparian Buffer Restoration

Location: Facing the river in an area where tree plantings and mature trees left from before the construction are visible.

Brochure Text: Contaminated soils were removed over a large portion of the Riverside Mills site in 2001-2002, as part of the overall Riverside Mills site clean up and re-development, and replaced with clean topsoil. During this process much of the vegetation near the immediate river edge had to be cleared. Remaining portions of the site, away from the immediate river edge, have lacked trees due to the mill buildings and grounds and previous uses (including possibly agriculture) for nearly two centuries or more. A few specimen trees along the river shoreline have persisted over the years, however, and were retained during the site clean up. For example, you can see a large silver maple from this station that germinated and grew on this site when it was a bustling mill site, continued to grow as the mill complex experienced hard times and was ultimately closed, and then persisted through site clean-up and re-development. Silver maple is one of Rhode Island’s native hardwood floodplain trees. It will provide a native seed source for the immediate shoreline and for areas downstream/downwind for years to come. Can you find a silver maple leaf on the ground? (they are much more deeply lobed than either red or sugar maple leaves). Many small trees, including silver maple, red maple, and white oak, were planted along the immediate river shoreline as part of the riparian buffer restoration. These are all native species found along undeveloped portions of the Woonasquatucket River in healthy floodplains as well as dryer river shorelines. Although the wooded buffer along the immediate shoreline is narrow, it is still performing many important water quality and wildlife habitat functions. Although optimal buffer widths are as large as several hundred feet or even several thousand feet, most urban areas cannot realistically achieve such widths and even a 10-foot buffer is far better than nothing.

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